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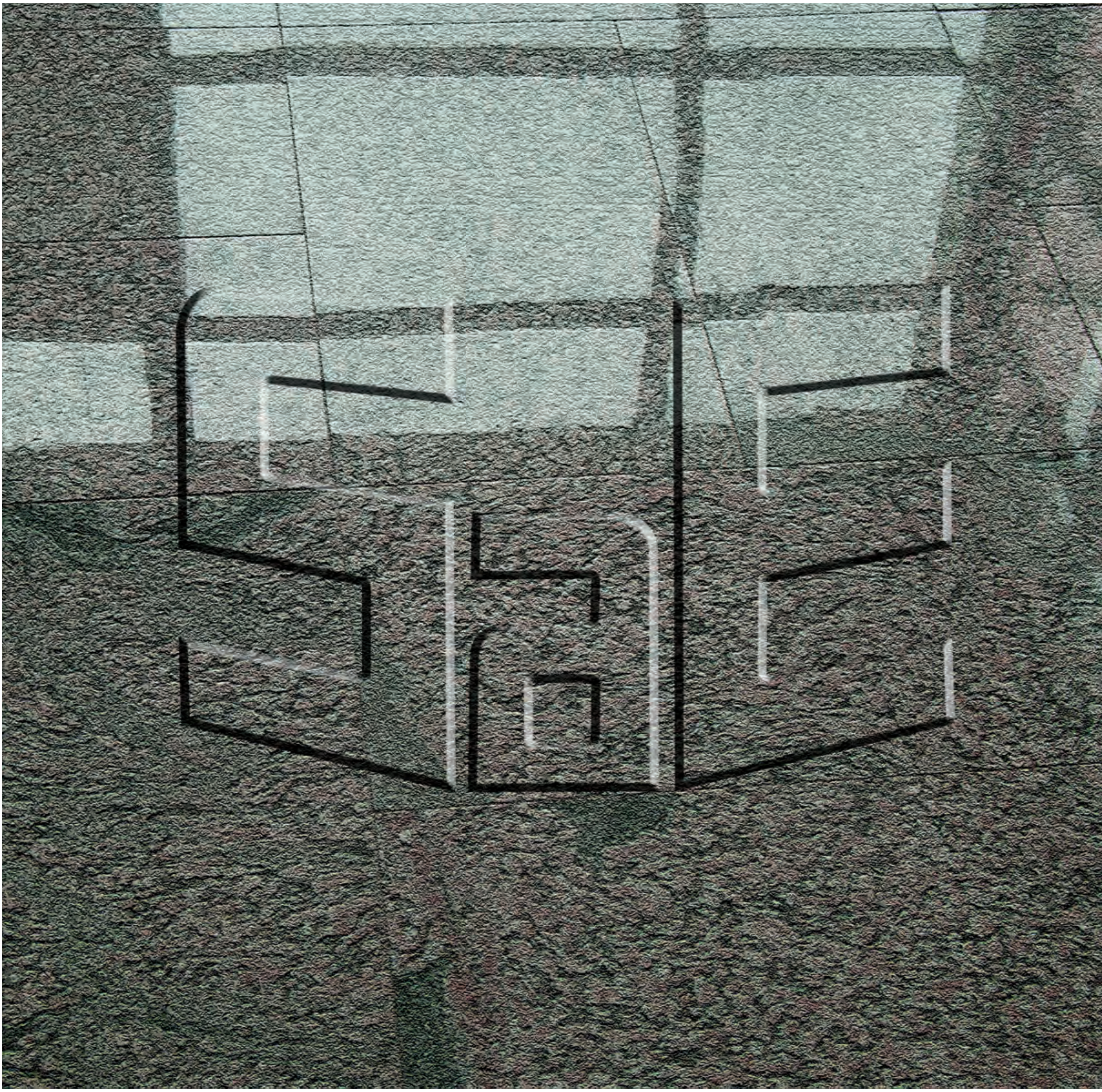

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CASE STUDY OF THERMAL COMFORT, LIGHTING CONDITIONS AND PRODUCTIVITY AT TWO CLASSROOMS OF POZNAŃ UNIVERSITY OF TECHNOLOGY

STUDIUM PRZYPADKU KOMFORTU CIEPLNEGO, OŚWIETLENIA I PRODUKTYWNOŚCI W DWÓCH SALACH DYDAKTYCZNYCH POLITECHNIKI POZNAŃSKIEJ

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Abstract

The paper analyses subjective sensations of thermal comfort, lighting conditions and self-reported productivity of 51 students of Poznań Univeristy of Technology (Poland). The study took place in the spring and was based on the use of anonymous questionnaires with questions on thermal sensations, acceptability and preferences as well as the students' assessment of their current productivity and lighting conditions. The test results indicate that the overwhelming majority was satisfied with thermal environment and lighting conditions in the rooms. Their general sensations were also largely positive, while self – reported productivity was generally assessed to be normal.

Keywords: thermal comfort, lighting conditions, productivity

Streszczenie

Artykuł analizuje subiektywne odczucia komfortu cieplnego, warunków oświetleniowych oraz produktywności 51 studentów Politechniki Poznańskiej. Badanie odbyło się wiosną i opierało się na wykorzystaniu anonimowych kwestionariuszy z pytaniami o odczucia cieplne, akceptowalność i preferencje oraz ocenę przez studentów aktualnej produktywności i warunków oświetleniowych. Wyniki badań wskazują, że zdecydowana większość była zadowolona z warunków termicznych i oświetlenia w pomieszczeniach. Ich ogólne odczucia były również w dużej mierze pozytywne, podczas gdy produktywność została ogólnie oceniona jako normalna.

Słowa kluczowe: komfort cieplny, warunki oświetleniowe, produktywność

1. INTRODUCTION

Indoor environment plays an important role in ensuring high level of comfort for living, working and studying. People's expectations regarding air quality and proper thermal sensations at homes, offices and public utility buildings are growing and building managers need be aware of the fact that the human's subjective feelings need to be addressed in terms of providing adequate indoor environment.

Thermal comfort has attracted a lot of attention in recent decades and it now an important element of civil and environmental engineering. Aghniaey et

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environment

al. [1] studied thermal comfort in eleven classrooms at the University of Georgia campus in the United States. There were 18 to 54 students in each room. The operative temperature ranged from 21°C to 27°C. The authors claimed that the thermal environment in the considered classrooms proved to be overwhelmingly acceptable. Operative temperature of about 23.5°C was taken as optimal at the considered location. Dębska and Krakowiak [2] conducted tests of thermal comfort using the questionaires as well as a microclimate meter. Eighty three people participated in the study. The optimal air temperature was determined to be ca. 22.5°C. The number of the dissatisfied for one room was quite significant (exceeding 50%) due to high air temperature of 27.6°C. The respondents generally considered humidity as fine or quite dry. The value of relative humidity in all the rooms was measured to be about 52%. Thermal comfort tests in the smart laboratory building located in Slovakia were presented by Kolkova et al. [3]. The authors considered the impact of two positions of the window blinds on employees' sensations. It was stated that the optimum temperature was not exceeded during the measurements. Kuchen and Fisch [4] conducted tests in twenty five office buildings in Germany in winter conditions. The total number of measurements amounted to 345. The value of the most preferred operative temperature varied from 21°C to 22°C.

The analysis of subjective productivity of Polish students was presented by Krawczyk [5]. The tests were done in the intelligent building of Kielce University of Technology (Poland). Over 80% of the respondents assessed their productivity as normal, while over 10% as weak. The study performed in the same building by Dębska and Białek [6] indicate that about 80% of the respondents considered lighting conditions there as suitable (followed by a "too weak" response from 15% of the people). The authors claimed that the actual satisfaction with lighting in the subjective opinion of the students started from the illuminance value of 430 lx.

It needs to be added that one of the problems related to the indoor environment is the occurrence of the sick building syndrome (SBS). Lis [7] presented an extensive study on the SBS symptoms observed in pre-school, school and flats of multi-family buildings. The volunteers complained mainly about the poor air quality (CO_2 concentration was over 1000 ppm in educational buildings) together with eyes irritation, headaches, respiratory tract as well as fatigue. It shows how important proper indoor environment is for human health and well – being. Moreover, Basińska et al. [8] analysed the use of portable devices in the Polish primary school building with the aim to assess the effectiveness of air purification device used in the experiments. The authors also considered indoor air quality taking into account microbiological contaminantion and particulate matter concentration.

The paper focuses on the subjective assessments of over fifty students regarding the indoor environment at two selected classrooms of Poznań University of Technology. The tests have been conducted with anonymous questionaires, so that the subjective sensations of each person could be collected and analysed.

2. MATERIAL AND METHOD

The study was aimed at determining the subjective sensations of 51 students expressed in the anonymous questionnaires during the classes. The measurements were performed in two separate buildings of the campus. One is a modern, recently developed building located in the Western side of the campus, while the other is a traditional building, a few decades old. Both are situated about three hundred meters from each other. Two rooms (each in a different building) were selected for the analysis: "room 1" with 30 students and "room 2" with 21 students. An example classroom/lecture room of Poznań University of Technology has been shown in Figure 1.

Fig. 1. Example classroom/lecture room of Poznań University of Technology

In total 27 women (53%) and 24 men (47%) took part in the study. Their age ranged from 19 to 24 y.o. The assessment was conducted on the same day. There were six questions in the questionnaire with a set of answers for each of them to choose from. The students ticked the appropriate box, if they felt that the answer, which they chose, properly described their sensations. The tests lasted about 5 minutes and the volunteers found the questions easy to answer. The first survey took place in the morning (about 9.15), while the second in the afternoon (about 13.40) during the regular classes. The students' clothes were "typical summer" with the clothing thermal insulation of ca. 0.6 clo. The room temperature in both the classrooms was comparable. The students were seated in about 2/3 of the classroom 1 and quite evenly in room 2.

3. RESULTS AND DISCUSSION

The first question aimed to determine the student's opinion on their thermal sensations at that moment. They expressed their opinions of the indoor thermal environment ranging from "too hot" (+3), through "hot" (+2), "warm" (+1) and neutral (0) to the negative values down to (–3), which meant "too cold". Figure 2 presents the results of the study as a frequency count of the answers for both rooms.

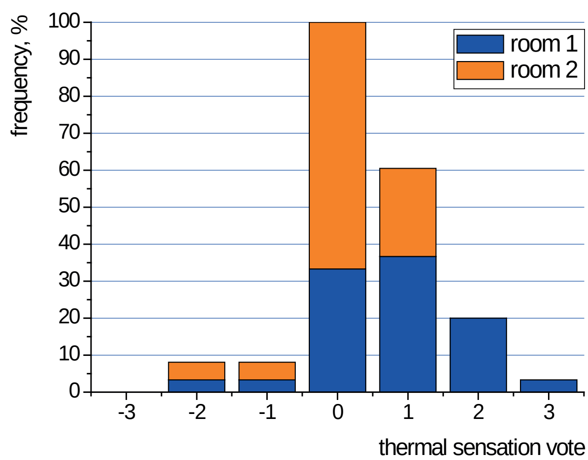

Fig. 2. Thermal sensation vote for two rooms

As can be seen the largest share of the answers was in the range 0 – 1, which indicates an overall positive assessment of the thermal environment. In room 1 twenty percent of the respondents considered the conditions as hot and 3.3% (one person) as too hot. It shows how subjective thermal environment might be (the conditions for all the students in each room were comparable e.g. none of them was subject to some excessive sources of heat and etc.). It needs to be added that the next question – on acceptability of the indoor conditions – proved that the respondents were almost completely (98%) in favour of the air temperature values in the rooms with 49% of the students considering it to be "comfortable" and 49% as "acceptable".

The next Figure 3 presents the students' willingness to change the state in the rooms regarding temperature. They might have opted for "much warmer" (+2) through "no change" (0) to much cooler (–2) environments.

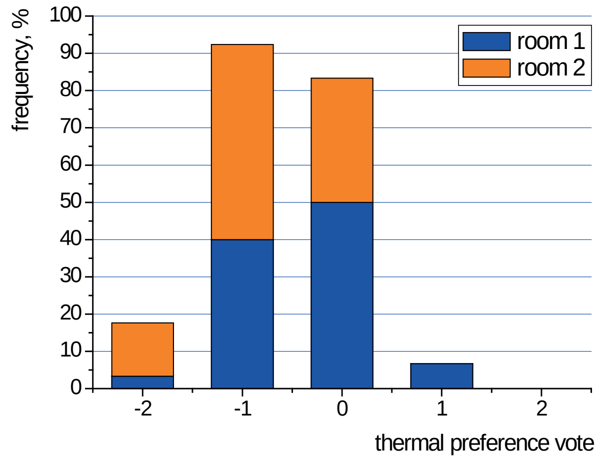

Fig. 3. Thermal preference vote for two rooms

Half of the students in room 1 did not want any change to their thermal environment, while quite many (40%) wanted to reduce the air temperature. A temperature reduction vote was very strong in room 2 (although the majority of the respondents felt fine there as shown in Fig. 2). It might be related to individual preferences of the students or the influence of other factors, not considered in this study (such as health, past activities before entering the class e.g. running). Typically the respondents would like to see a temperature reduction in the warm environment and the opposite would be true for cold environments. The relation of the mean values of random five answer pairs on thermal sensation and preference has been presented below in Figure 4 and it supports the above mentioned statement.

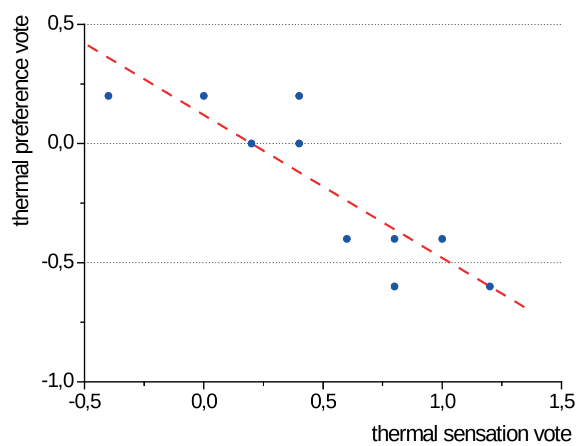

Fig. 4. Thermal preference vote (TPV) vs. thermal sensation vote (TSV) for both rooms

The obtained correlation takes the form of TPV = -0.6TSV+0.12 with the R^2 value of 0.76.

The students were also asked to assess the lighting conditions in the classrooms. Naturally, the level of illuminance is easily regulated and for classrooms should meet the requirements of adequate standards. However, in this study only a subjective assessment has been conducted. The results have been presented in Figure 5. The largest majority of the respondents considered the conditions as acceptable (0), only some thought the it was too strong (+1) or too weak (–1) – this answer was provided by almost 24% of the students in room 2. This might be related to both individual preferences as well as the location of the students in the room.

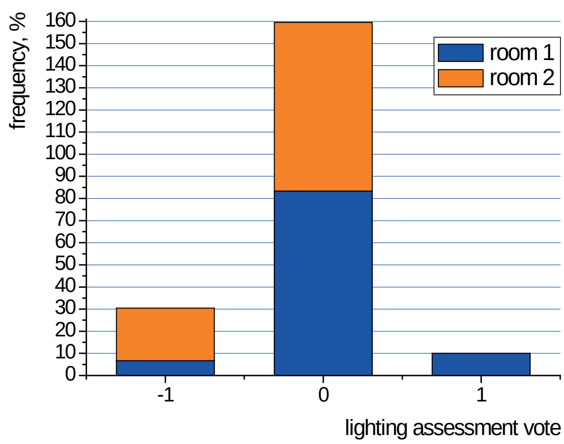

Fig. 5. Assessment of lighting conditions for two rooms

The students who participated in the study were also asked about their learning potential due to the fact that the indoor environment might have a significant impact on productivity (apart from other factors such as health, outside noise and etc.). The possible answers on self – reported productivity were: normal (0), high (+1) and weak (–1). The results of the investigation has been shown in Figure 6 for both the rooms separately.

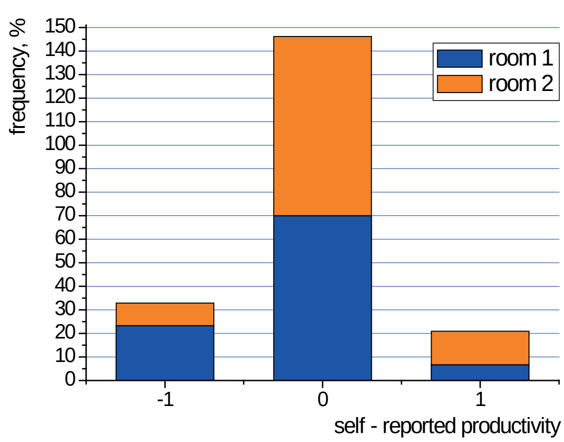

Fig. 6. Self – reported productivity for two rooms

The largest group of students in both rooms considered their productivity (learning potential) as normal. Some (especially in room 2) thought that it was higher than normal, while some (especially in room 1) regarded it to be weak. Obviously, there might be many reasons influencing the result, for example the timing of the measurements (morning/afternoon), personal issues (e.g. hunger, tiredness, illness) and others not necessarily related to the surrounding environment.

The last question in the questionnaire dealt with a general feeling of the respondents, namely how they felt in the rooms. The possible answers ranged from "very well" (+2), through "neutral" (0) to "very bad" (–2). Again, this subjective assessment is only partly related to the indoor conditions and other factors might play a decisive role (such as the state of health, personal problems and etc.). The results of the study have been presented in Figure 7.

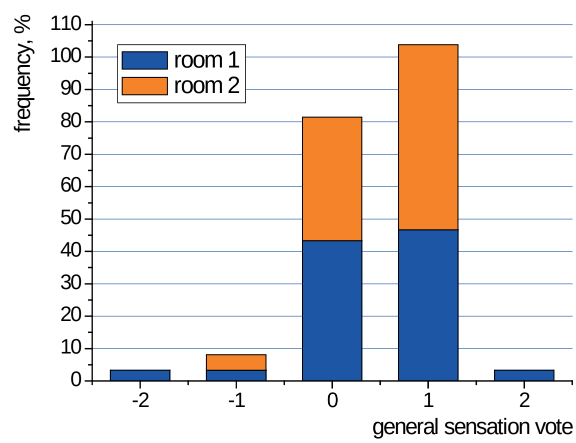

Fig. 7. General sensations of the students in two rooms

Data presented in Figure 7 reveals that the overwhelming majority of the students considered their state to be either well or neutral. It is worth noting that in room 1 one person felt "very well" and also one felt "very bad". Such "extreme" cases can occur especially in a large group and might not be linked with the indoor conditions prevailing in the closed space.

The general sensations experienced by a person might influence his/her productivity. When people feel well, their learning potential can be improved. Figure 8 presents the data of self – reported productivity vs. general sensation vote for 51 students (the largest dot on the graph represents 19 identical responses, while the smallest dots – one response) together with the linear fitting.

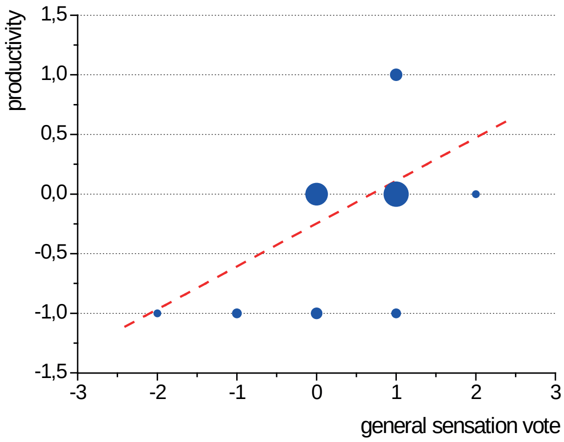

Fig. 8. Self – reported productivity (P) vs. general sensation vote (GSV) for both rooms

The analysis of the figure leads to a conclusion that a relation might exist between the person's self – reported productivity and subjective general sensation vote. The number of people participating in the study was limited to only 51 people. Consequently, drawing more general conclusions on this issue might be difficult. The resulting correlation took the formula of P = 0.36GSV-0.25 with the R^2 value of only 0.23.

4. SUMMARY AND CONCLUSIONS

The conditions of indoor environment considerable influence people's sensations and their well – being. One of the most important aspects is providing and maintaining thermal comfort. The study analysed the subjective assessment of fifty one students. It was found that the overwhelming majority was satisfied with their thermal environment as well as lighting conditions in the considered two classrooms. Their general sensations were also largely positive, while self – reported productivity was generally assessed to be "normal" (ca. 70% of such a response in each group). Broadening the experimental database might provide more insight into the nature of subjective human sensations in various indoor environments.

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GEOTECHNICAL INVESTIGATION OF BORROW PIT AS A SUBGRADE MATERIAL FOR ROAD CONSTRUCTION AT VICTOR ATTAH INTERNATIONAL AIRPORT, UYO, NIGERIA

BADANIE GEOTECHNICZNE MATERIAŁU Z WYKOPU JAKO PODŁOŻA DO BUDOWY DRÓG NA MIĘDZYNARODOWYM LOTNISKU VICTOR ATTAH, UYO, NIGERIA

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Abstract

One of the mass prompt practices of soils is for engineering projects such as the construction of roads, buildings, dams, and so on. Therefore, suitability of index and mechanical properties needs to be investigated. This study aims to determine the essential quality material required for road construction, thereby poses détente prospect for the disposal of ineffectual atrophy generated on sites. Such materials are classified into index and mechanical properties. Six subgrade samples were taken at the depth to bottom ranging from (1.0-5.0) m and tested. The sample was subdued to the laboratory tests, such as Sieve Analysis, Atterberg limits, compaction, California Bearing Ratio (CBR), and Specific Gravity (SG) respectively. The mechanical analysis which involved particle size distribution revealed that the subgrade was finely grated with a limit of ≤35% for subgrade passing sieve No. 200 (0.075 mm) with 29.1%, with an average Natural Moist Content (NMC) of 13.9%. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were 1.83 mg/m^3 and 11.5%. The index analysis involved the liquid and plastic limits determination of Liquid Limit (LL) of 35.8%, Plastic Limit (PL) of 24.0%, and a Plasticity Index (PI) of 12%. California Bearing Ratio (CBR) results were 20.3% (soaked). The SG test results ranged from (2.68-2.94) kg/m^3, employing the American Association of State Highway and Transport Officials (AASHTO) system of soil classification. The AASHTO grouped the materials into A-1, subgroups A-1-b and A-2-4 constituting 50% and 29.1%, with significant materials composed of stone fragments and sand rating the subgrade samples as excellent to good materials suitable for road construction.

Keywords: Lateritic, Liquid Limit, Plasticity Index, Subgrade

Streszczenie

Jedną z masowych praktyk związanych z gruntami są projekty inżynieryjne, takie jak budowa dróg, budynków, zapór itp. Dlatego należy zbadać przydatność gruntu i jego właściwości mechaniczne. Niniejsze badanie ma

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na celu określenie niezbędnych właściwości materiału wysokiej jakości wymaganego do budowy dróg, co stwarza perspektywę usunięcia nieefektywnych wykopów generowanych na terenie. Materiały są klasyfikowane według wskaźników i właściwości mechanicznych. Sześć próbek gruntu pobrano z głębokości w zakresie 1,0-5,0 m i poddano badaniom. Próbki zostały poddane testom laboratoryjnym, takim jak analiza sitowa, granice Atterberga, zagęszczenie, kalifornijski wskaźnik nośności (CBR) i ciężar właściwy szkieletu gruntowego (G_S). Analiza rozkładu wielkości cząstek wykazała, że grunt był drobnoziarnisty o uziarnieniu ≤35% dla sita nr 200 (0,075 mm) oraz 29,1%, przy średniej naturalnej wilgotności gruntu (W) wynoszącej 13,9%. Maksymalna gęstość szkieletu gruntowego (ρds) i optymalna zawartość wilgoci (Wopt) wyniosły odpowiednio 1,83 mg/m³ i 11,5%. Wyznaczono granice płynności i plastyczności: granica płynności (wL) wynosiła 35,8%, a granica plastyczności (wp) 24,0% oraz wskaźnik plastyczności (Ip) na poziomie 12%.

Kalifornijski wskaźnik nośności (CBR) wyniósł 20,3% (po nasiąkliwości). Wyniki badań G_S wahały się od 2,68 do 2,94 kg/m³, przy zastosowaniu systemu klasyfikacji gruntów AASHTO. Według AASHTO pogrupowano grunty na A-1, podgrupy A-1-b i A-2-4 stanowiące 50% i 29,1%, przy czym materiały składające się z odłamków kamieni i piasku oceniono jako doskonałe lub dobre materiały nadające się na budowy dróg.

Słowa kluczowe: lateryt, granica płynności, wskaźnik plastyczności, grunty

1. INTRODUCTION

Globally, inaccessible to infer suitable data about the index and mechanical properties of the soil and subsoil condition of the region, especially for primary prior engineering projects, antiquated and cause failures on road construction projects (Fidelis et al., 2019; Robert et al., 2020). That is, a failure immediately after the project is commissioned or even before commissioning. It is essential for the engineers, geoscientists, and soil scientists designing road construction projects to have a good knowledge of the geotechnical, index, and mechanical parameters of the subgrade material before any construction commences (Malomo, 1977; Ola, 1978; Adeagbo, et al., 2016). The various properties of subgrade soil are grouped into; index properties and engineering properties (Ramamurthy and Sitharam, 2005; Osinubi et al., 2019). The mechanical properties of subgrade soils are permeability, compressibility, and shear strength while the index properties are particle size distribution, Atterberg limits, density index, and specific gravity of soil particles (Agbede, 1992; Hunt, 2007). These soil properties are mainly used in the identification and classification of soils and help the geotechnical engineer in predicting the suitability of soils as foundation and construction material (Coduto, 2007; Aroka, 2009; Ola, 1978). In this study, selected borrow pits around Ndon Ebom Uruan, Akwa Ibom, Nigeria was investigated and used as the subgrade. These borrowed pits were originally entrenched as a source of road fill material and are nowadays the source of red earth material for nearby construction sites and other civil engineering work (Lancellotta, 2009: Godwin et al., 2020). A borrow pit is a term used in construction for a hole, pit, or excavation that has been dug to remove gravel, clay, and sand used in a construction project such as bridges, dams, and so on (Salter, 1988; Oglesby and Hicks,1992; Ogbuagu and Okeke 2019). Borrow pit site investigations are primarily carried out to establish reliable estimates of the quantity, quality, and processing needs of potential road building materials. These materials suitable for filing surfacing or blending can be removed using earthmoving equipment. A borrow pit can also be referred to as a sandbox, a large hole that has been dug for a particular purpose. Almost all construction projects involve earthwork designed to determine a suitable base for engineering construction (Malomo, 1977; Singh, 2004). A key aspect is to ensure that ground conditions are sound for stable construction through grading and excavation processes. Frequently, constructions crews will dig borrow pits to gather gravel, soil, and sand for use in another location (Opeyemi et al., 2018). The digging of borrow pitfalls under the engineering discipline known as earthworks. Earthworks projects consist of engineering exploits including, the transportation of large amounts of soil or rock from one area to another. Borrow pit construction may seem relatively easy to accomplish, though this type of digging requires an extensive amount of analysis before the original dig (Charkley et al., 2019). Engineers and Geoscientists must be sure that the amount of soil dug from a pit in an area will not disrupt the earth. Before the invention of geotechnical engineers, geoscientists, and other soil scientists needed to calculate the degree to which the earth desired displacement during digging (AASHTO, 2000; Murthy, 2007). As well as the accuracy in the laboratory, modern equipment on quality and sampling techniques was applied and data interpreted. On the other hand, it poses the rationale for the growth and development of the state, and other places around the world as the international airport good road attracts investors globally (Onakunle et al., 2019). Hence, this research aids to provide geotechnical data for engineers, geoscientists, and contractors for use as engineering subgrade and base materials as well as educating the fresh research worker.

2. GEOLOGY AND LOCATION OF THE STUDY

The borrow pit is located at Ndon Ebom Community, Southern Uruan in Uruan Local Government in Akwa Ibom State, Nigeria, about 1500 m away from Victor Attah International Airport, South-South Nigeria. It lies between latitudes 4°90'N and longitudes 8°08'E covering an area of about 449 km^2, as shown in Figure 1.

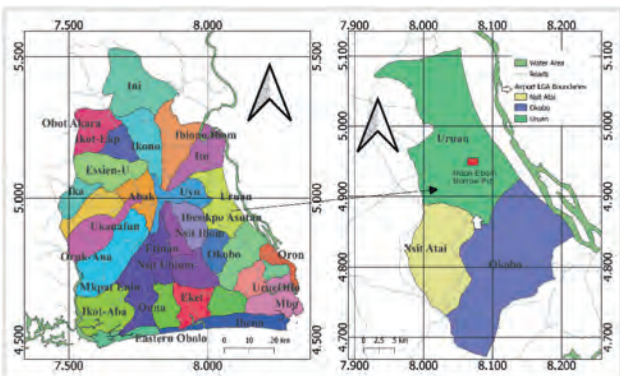

Fig. 1. Location of the study area citing Ndon Ebom (Borrow pit) and Airport

The Borrow pit is sited away from the residential areas and major roads to prevent the environmental hazard. The subsoil material is lateritic in color with an enclosure of coarse particles with conceivably enhanced particle size distribution. The lateritic material possesses clayey properties which influence the acceptability level of compaction for road construction and other engineering projects (Malomo, 1977; Aka et al., 2021). The topography of the area is tabled land with a gentle slope accompanied by natural vegetation consisting of grasses, economic and commercial trees, and shrubs. Geologically, the parent rock materials within the area are mainly sedimentary rocks which have resulted in the prevalence of sandy-clayey soils lithology as shown in Figure 2 (Aka et al., 2020a; Avbovbo, 1978; Aka et al., 2020b).

Fig. 2. Borrow pit formation in Ndon Ebom lithology with a heavy-duty excavator at work

3. MATERIALS AND METHODS

Borrow Pit Sampling

The sampling method covers procedures for recovering soil samples to investigate the soil for use as a borrow pit. The test was carried out in reference to American Society for Testing and Materials (ASTM) International, which is a standard test method for analysis of Soils. The pits were assigned: numbers, names, sites, and locations in consecutive order for filing purposes, and references of the pit.

Apparatus: The apparatus used for the sampling include: Posthole auger with handle extensions of (50 -300) mm in diameter that is capable of extending by adding sections to the handle for boring the marked point on the field into the holes to achieve the desired depth. Accessory Equipment such as Sample tag for identifications of samples, sample bags for collection of samples taken out from auger to the laboratory, shovel for clearing of access way and point of boring, tape for measurements of sample distance, a permanent marker for writing on sample bags.

Procedure: The area was taken out for testing using a grid pattern with number labeling on-site and the location at about 1.0 m intervals for areas where soils vary unpredictably and 2.0 m intervals for areas where soils are reasonably uniform respectively. The hand auger is made boring by turning the auger to a desirable distance, say (1-5) m into the soil, withdrawing the auger, and removing the soil for sampling. The process was repeated for the three sets of data acquired and the samples of each soil type, except topsoil, were taken. Stockpiles were involved in the sample during the stockpiling operation by obtaining characteristic samples using a shovel sampled as specified after the stockpile is complete. Place the sample in the bag and complete the

environment

identification tag for the sample, depth to the nearest half afoot, of the top and bottom of the soil strata from which the sample was taken. After sampling is complete the stake bearing the site and location number was reset to mark the location. Then a map is drawn for referencing each location of the site presently being tested to landmarks with the legend indicating the name and number of the pit, district, name of the contractor, type of borrow, contract number, date sampled, names of the sampling crew, and the scale used to draw the map. Lastly, the bagged samples were returned to the laboratory for testing (ASTM D 698, 2012).

4. LABORATORY TESTS

Moisture Content (W)

The moisture content of the soil also referred to as water content, is an indicator of the amount of water present in the soil. It is the ratio of the mass of water contained in the pore spaces of soil to the solid mass of particles in that material, expressed as a percentage. A standard temperature of 110°C ±5°C is used to determine the mass of the sample.

5. SAMPLE PREPARATION FOR MOISTURE CONTENT

Apparatus: The apparatus involved includes: non-corrodible container, and vented thermostatically controlled drying oven that maintains temperatures between 105°C to 115°C, a balance of sufficient sensitivity (sensitive to 0.01 g), and Container handling apparatus.

Procedure: The container was clean, dry, and weighed empty balance, tarred before it is used to measure the weight W_1. The weight of the container and wetness of the soil sample of the specimen in the container was measured as W_2. The container was kept in the oven for 24 hours, drying the specimen to a constant weight, maintaining the temperature between 105°C to 115°C, and recording the final constant weight W_3 of the container with the dried soil sample (Head, 1994a; ASTM D 698, 2012). The moisture content of soil (W)

$$W = \frac{M_w}{M_s} \times 100\% \quad (1)$$

where: M_w = weight of container + wet of soil W_2 – weight of container + dry soil W_3,
M_s = weight of container + dry soil W_3 – weight of container W_1.

6. PARTICLE SIZE ANALYSIS

Mechanical analysis (particle size distribution) is the determination of the size range of sand, silt, and clay present in a soil expressed as a percentage of the total dry weight.

7. SAMPLE PREPARATION FOR PARTICLE SIZE ANALYSIS

Apparatus: The apparatus set up were: Drying oven maintained at 110°C ±5°C, Standard sieves, Sample splitter, Mechanical sieve shaker, and Pans.

Procedure: The procedure consists of the following: drying the soil sample in an oven for 24 hours to get rid of moisture, measuring 500 g of the dry sample, and soaking in water for 24 hours. Record the weight of the sieves and the pan that will be utilized during the analysis. Each sieve should be thoroughly cleaned up before the test. Assemble the sieves in ascending order, by placing those with the larger openings on top. That is, the No. 4 were placed on top and the No. 200 sieve on the bottom of the stack. Place the soil sample into the top sieve and place a cap/lid over it. Place the stack in a mechanical shaker and shake for 10 minutes. After the sieve stack was removed from the shaker and measure the weight of each sieve and that of the pan were placed at the bottom of the stack. Lastly, the weight of the soil retained on each sieve was calculated by subtracting the weight of the empty sieve from the recorded weight of the sieve after the test. The total weights of particles retained were added and compared to the initial weight of the soil sample. A difference lower than 2% was required which is a standard. The percentage retained on each sieve is determined by dividing each weight retained by the initial weight of the soil sample. Subsequently, the total percentage passing from each sieve was calculated by subtracting the cumulative percentage retained in that particular sieve and the ones above it from the totality (ASTM D422, 2007). On the other hand, the grain size distribution curve of medium-fine sand was plotted to calculate the uniformity coefficient (C_u) expresses the variety in particle sizes of soil ratio of D_{60} to D_{10}. The value D_{60} is the grain diameter at which 60% of soil particles are finer and 40% of soil particles are coarser, while D_{10} is the grain diameter at which 10% of particles are finer and 90% of the particles are coarser.

$$C_u = \frac{D_{60}}{D_{10}} \quad (2)$$

when C_u is greater than 4, the soil is classified as well graded; whereas when C_u is less than 4 the soil is classified as poorly graded/uniformly graded (Head, 1994b).

8. COMPACTION

Compaction of soils is a procedure in which soil sustains mechanical stress and is densified. This was carried out to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The mechanical stress may be applied by kneading, or via dynamic or static methods (Didei and Oborie 2018). The degree of compaction is quantified by measuring the change of the soil's dry unit weight (γ_d), as a result of an increase in the strength of soils, and a decrease in incompressibility and permeability of soils.

Apparatus: The apparatus utilized to conduct the test include: a 10-centimeter diameter cylindrical compaction mold equipped with a base and a collar, a Proctor rammer weighing 2.5 kg or 4.5 kg depending on whether the standard of the modified test is conducted, No. 4 Sieve Steel straightedge, Moisture containers, Graduated cylinder, Mixer, Controlled oven, Metallic tray, and a scoop.

Procedure: Four soil samples were obtained and measured at about 3 kg each. 2% of water was added to the first portion and mixed thoroughly. The other was kept in separate cans to determine the weight of both wet and dry samples after 24 hours of placement in the oven to determine the moisture content. The first portion of the sample was compacted and mixed with a proctor mold using a 4.5 kg rammer in 3 layers of 27 blows per layer. The same procedures were taken for the remaining layers and rammed 27 times each. The weight of the compacted wet sample was weighed using a weighing balance and calculates the wet density respectively. The procedure was repeated for the remaining three portions with 4% to 12% volume of water till the value of the compacted soil and mold drops. Finally, the compaction water content (W) of the soil sample was calculated using the average of the three measurements obtained from the top, middle and bottom part of the soil mass along with dry unit weight (γ_d) (ASTM D 698, 2012):

$$\gamma_d = \frac{W - W_m}{(1+w)\times V} \tag{3}$$

where: W = the weight of the mold and the soil mass (kg), W_m = the weight of the mold (kg), W = the water content of the soil (%) and V = the volume of the mold (m^3).

The procedure was repeated four times, for a given selected water content from lower to higher than the optimum. Hence, the calculated dry unit weights were plotted against their corresponding water contents to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) along the Zero Air Voids at a 100% saturation line. On the other hand, the Zero-Voids curve is calculated as follows:

$$\gamma_d = \frac{G_s \times \gamma_w}{1 + W \times G_s} \tag{4}$$

where: G_S – the specific gravity of soil particles, γ_w – the saturated unit weight of the soil (kN/m^3), W – the water content of the soil (%) (Head, 1994a).

9. ATTERBERG LIMIT

The Atterberg limits test is named after the Swedish chemist Albert Atterberg who was the first to develop a classification system to determine the different states and limits of soil consistency. The Atterberg limits test, also known as consistency, is used to determine the moisture content at which a soil changes from solid, semi-solid, plastic, and liquid states (Godwin et al., 2020). It is used to distinguish between silt and clay and determines the shrinkage limit (SL), plastic limit (PL), and liquid limit (LL) of the soil sample. The Atterberg test is performed only on soil fraction that passes through sieve No. 40 (ASTM D 4318, 2010).

Apparatus: The apparatus were: Evaporating dishes to mix specimen to desired moisture content, spatula to mix, form and smooth the soil specimen, aluminum containers for soil moisture samples, mortar and pestle to reduce particle size, digital scale with 0.01 g readability, drying oven for moisture content test, liquid limit test accessory set including liquid limit machine and Casagrande grooving tool, plastic limit test apparatus including plastic limit roller and glass plate, shrinkage limit test apparatus including shrinkage dish, microcrystalline wax, petroleum jelly, fine thread, glass plate, and wax melting pot.

Procedure: 150 g air-dry soil samples passing sieve No. 40 were used. The Moisture was adjusted by adding 20% of water to the soil sample and mixing thoroughly. The samples were allowed to condition for at least 16 hours. For the liquid limit (LL) Test, a small portion of the soil sample was spread in the brass cup of the liquid limit device case grinder. A groove was cut to at least a 2 mm base with a grooving tool, turns the device and notes the number of blows (N) and stop when the groove in the soil closes. Finally, a sample and oven-dry were taken to find the moisture content. The tests were repeated three times and plotted the moisture content against the number of blows to determine LL, PL, and SL (ASTM D 4318, 2010).

10. CALIFORNIA BEARING RATIO (CBR)

The California Bearing Ratio Test (CBR) is a penetration test developed by the California State Highway Department (U.S.A.) for evaluating the bearing capacity of subgrade soil for the design of roads and pavement. The tests are carried out on natural or compacted soils in water-soaked or unsoaked conditions and the results obtained are compared with the curves of the standard test to have an idea of the soil strength of the subgrade soil (Akaolisa et al., 2021).

Apparatus: The apparatus involved are: mold, steel cutting collar, spacer disc, surcharge weights, dial gauges, IS sieves, penetration plunger, and loading machine.

Procedure: Soil samples were measured at about 6 kg, added water to the sample, and mixed thoroughly. Using a 2.5 kg rammer, weight of empty mold, compact the mixed sample into three (3) layers with 61 blows per layer. After compaction, the collar was removed, level the surface, and taken a sample to determine moisture content. Record the weight of mold + compacted specimen respectively. Mold was placed in the soaking tank for four days for soaked and ignored for unsoaked (Ojuri et al., 2017). The process was repeated for another set of samples after four days, measuring the swell reading and finding the percentage swell. After, the mold was removed from the tank and allowed water to drain. Then the soil sample was placed under the penetration piston and placed a surcharge load of 2.5 kg, applied the load, and noted the penetration load values were. Finally, the graph of piston load against penetration was plotted to determine the value of CBR, along with % CBR versus Dry Density to find CBR at the required degree of compaction (ASTM D 4318, 2010).

11. SPECIFIC GRAVITY (SG)

Specific gravity is a fundamental property of soils and other construction materials. It is the ratio of material density to the density of water and is used to calculate soil density, void ratio, saturation, and other soil properties with a dimensionless unit (Akaolisa et al., 2021). It is applicable in the foundation design for structures, calculations for the stability of soil embankments, and estimations of settlement for engineered soil fills.

Apparatus: Two density bottles of 50 ml capacity with stoppers at 27.2°C water bath, vacuum desiccator, oven, capable of maintaining a temperature of 105°C, spatula and weighing balance with an accuracy of 0.001 g.

Procedure: The density bottle along with the stopper was dried to a temperature of 105°C, cooled in the desiccator, and weighed to the nearest 0.001 g (W_1). The sub-sample, which had been oven-dried, was transferred to the density bottle directly from the desiccator for cooling. The bottles and contents together with the stopper were weighed to the nearest 0.001 g (W_2). The soil sample was covered with air-free distilled water from the glass wash bottle and left for a period of 2 hours for soaking. After the water was added to fill half a bottle and entrapped air was removed by heating the density bottle on a water bath, and keep the bottle without the stopper in a vacuum desiccator for about 1hrs until there is no further loss of air. Then the soil was gently stirred in the density bottle with a clean glass rod. The process was repeated till no more air bubbles were observed in the soil mixture and recorded by inserting the stopper in the density bottle, wiping, and weighing it (W_3). Lastly, the bottle was empty, cleaned thoroughly, and filled the density bottle with distilled water at the same temperature. Insert the stopper in the bottle, wipe dry from the outside and weigh it (W_4), (Head, 1994b; Ihekweme et al., 2021). After this process, the density of the soil particles (along with the specific gravity) were calculated as shown:

$$\rho_s = \frac{(W_3 - W_1) \times \rho_w}{(W_2 - W_1) - (W_4 - W_3)} \tag{5}$$

$$G_s = \frac{\rho_s}{\rho_w} \tag{6}$$

where ρ_w is the density of water = 997 kg/m^3.

12. RESULTS AND DISCUSSION

The results of the geotechnical investigation carried out in the laboratory on the soil samples collected from the study area are summarized and presented in Table 1.

Table 1. Summary of Geotechnical properties of the collected soil samples

PROPERTIES / SAMPLES	A	B	C	D	E	F
(1) Index Properties						
Colour	Red sandstone	Reddish-brown	Grey wacke	Reddish-brown	Grey - brown	Grey
(a) Atterberg Limits Test						
Liquid Limit (%)	68.49	63.69	71.88	64.75	41.87	41.69
Plastic Limit (%)	61.23	57.23	63.90	58.86	31.51	28.29
Plasticity Index (%)	7.26	6.46	7.98	5.89	10.36	13.4
Moisture Content (%)	37.5	36.1	35.7	33.9	24.1	23.9
Number of blows	10	18	29	37		
(b) Specify Gravity Test						
Specific Gravity (G_S)	2.41	2.76	2.80	2.94	–	–
Density of the Soil Particle (ρ_s) kg/m^3	2.403	2.752	2.792	2.931	–	–
Number of blows	10	18	29	37	–	–
(a) California Bearing Ratio (CBR) Test						
Load (kg)	0.5 1.0	1.5 2.0 2.5	3.0 3.5	4.0 4.5	5.0 5.5 6.0	6.5 7.0
Penetration (mm)	0.06 0.44	0.73 1.04 1.39	1.74 2.06	2.44 2.78	3.42 3.48 3.80	4.12 4.44
% CBR value	11.7			20.3		
(2) Mechanical Properties (a) Compaction Test						
Water Content (%)	7.9	9.6	11.5	12.7	14.1	14.2
Dry Density (mg/m^3)	1694	1725	1830	1770	1737	1736
Optimum Results	Maximum Dry Density (MDD) = 1.83 mg/m^3			Optimum Moisture Content (OMC) 11.5%		
(b) Sieve Analysis Test						
Percentage Passing (%)	100.0	98.3	86.9	52.7	32.4	29.1
Opening Diameter (mm)	2.36	1.18	0.600	0.300	0.150	0.075
Uniformly Coefficient (C_u)	4.0			8.0		

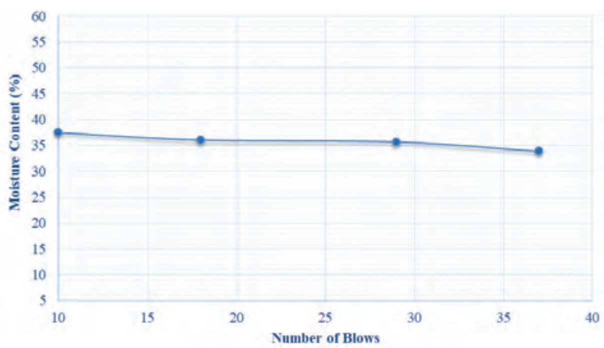

Fig. 3. A plot of moisture content (%) against number of blows on Atterberg limit test

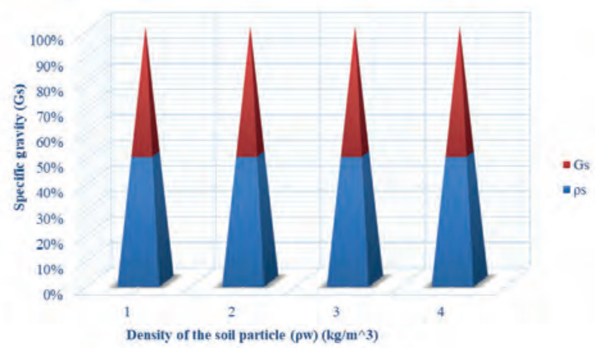

Fig. 5. Variations in specific gravity (G_S) against density of the soil particle (ρ_w) (kg/m^3)

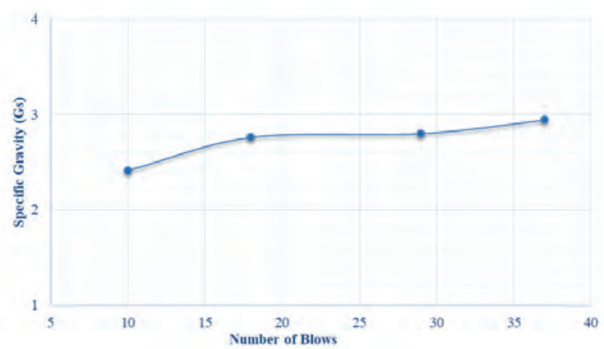

Fig. 4. A plot of specific gravity (G_S) against number of blows

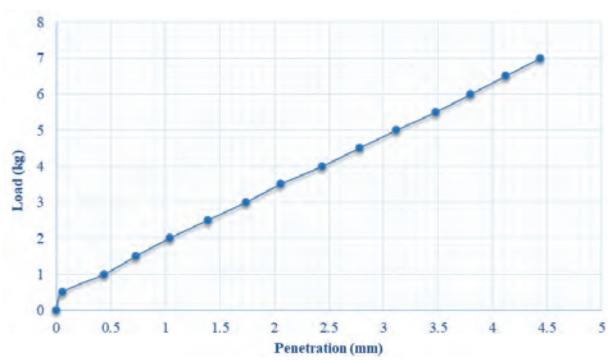

Fig. 6. A plot of load (kg) against penetration (mm) on CBR test

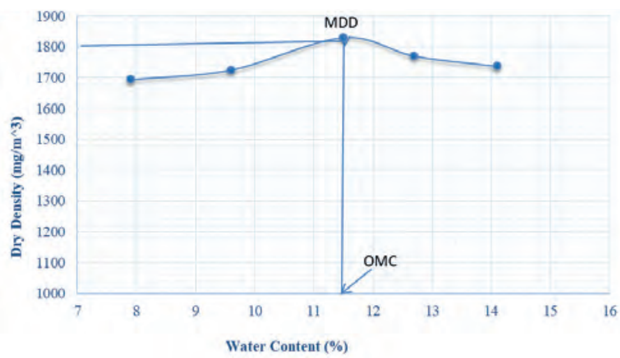

Fig. 7. A plot of dry density (mg/m^3) against water content (%) on compaction test

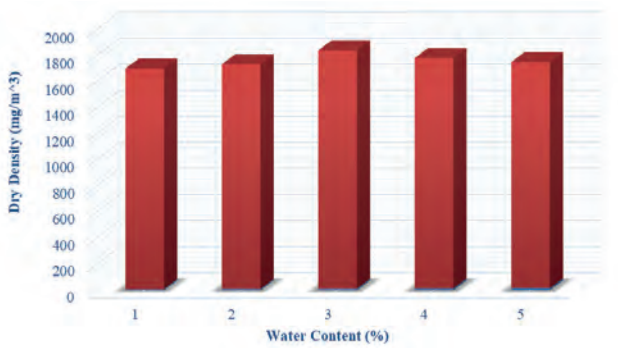

Fig. 8. Variations in dry density (mg/m^3) against water content (%)

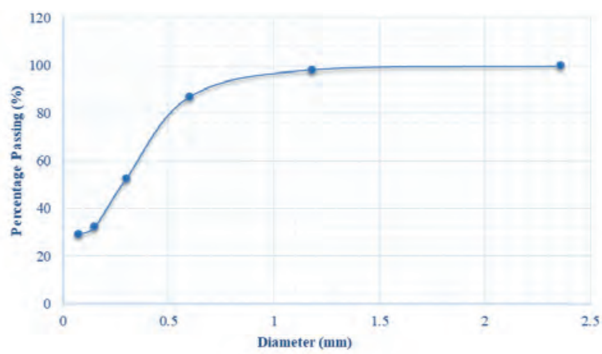

Fig. 9. A plot of the percentage passing (%) against diameter (mm) on sieve analysis test

The result obtained from the geotechnical analysis test was classified based on the AASHTO standard and compared quantitatively by specifications to establish if the material is the same quality throughout and evaluate scattering results errors. The analyzed result was summarized and presented in Table 1. In the Index properties: geologically, the coloration of the samples ranged from red sandstone to reddish-brown, greywacke to greyly brown. Pursuant to (Brady and Weil, 2010), the reddish to brown deposition indicates the presence of iron oxide, and greywacke indicates immature sedimentary sandstone deposition of mud and sand applicable for road construction. The Atterberg limits analysis as depicted in Table 1, shows the plasticity graphical illustration for USCS with a Plastic Limit (PL) average of 24.0%, a Liquid Limit (LL) of 35.8%, and a Plasticity Index (PI) of 12% as shown in Figure 3. This Conform to F.M.W & H specification requirements for LL and PI of not more than 35% and 12%, determined by the American Society for Testing Materials Method (ASTM D422, 2007). Also, attest, the subgrade is suitable to be used in road construction since LL and PI values do not exceed the standard limit of 35% and 12% respectively. However, based on (AASHTO, 2000) and (USCS, 2006) comparison, samples A to D were classified as sandy silt formations whereas E to F were clay formations respectively. The clay is greater than 10% realized in the acquired samples according to a fair to high-rise plasticity index of sampling. This gives an intimation of the prospects to productively restrain dilapidation waged being foot covering during dumpster diving (EPA, 2014). On the other hand, soils with regards to high-rise clarity indulge breathe prone to bulk shrinking (Rowe et al., 1995). Conforming to (Guney et al., 2014), for soil to be potent sheathing substantial, fragment dimensions are requisite to mollify at the minimum of (15-20)% clayed-sized materials with plasticity of greater than 10%. The density of the soil particles was found to range from (2.41-2.94) kg/m^3 with an average value of 2.73 kg/m^3 across the soil layer of the borrow pit. This exhibits a continuous periodic displacement of particle soil density concerning several blows as shown in Figure 4. Moreover, the comparison of G_S with soil density was done to ascertain its data sets as illustrated in Figure 5. It also shows that the subgrade sample of the borrow pit is primarily of good lateritic material, according to the specification of specific gravity ranging from 2.5 to 2.75. From Table 1, the result revealed a CBR value of 20.3% at 48 hours of soaking. Based on (ASTM D422, 2007) specification requirements, the minimum strength for subgrade should not be less than 10% after at least 48 hours of soaking and not less than 80% un-soaked. Therefore, the 20.3% CBR soaked value obtained is good for road construction as required in the specification. However, Figure 6 shows linear variations of the load (kg) against penetration (mm). This implies an increase in penetration, increasing the load-bearing capacity of the road and its strength. In mechanical properties: the Natural Moisture Content (NMC) of earth materials from the borrowed pit ranges (from

7.9 to 14.1)% with an average of 13.9%. The low value obtained in some areas revealed that NMC loses moisture readily in its natural state. The MDD and OMC values of 1.83 kg/m^3 and 11.5% were depicted as illustrated in Figure 7 with a vertical comparison between dry density water content as shown in Figure 8. This variation in MDD and OMC values of the sample revealed that the subgrade samples are better classified due to their conformity to absorb less water increase on drying which promotes robust construction works. The sieve analysis in Table 1 shows the range and distribution of various sizes of particles. The values range from (0.075-2.36) mm in line with the Federal Ministry of Work and Housing (F.M.W&H) specification requirement for subgrade samples. The percentage base on the limit of ≤35% for subgrade was 29.1% passing sieve No. 200. This required no need for advanced tests on samples, revealing good subgrade samples. The plot of a percent (%) passing sieve analysis in Figure 9, shows that the soil is well-graded, ranging from (0.075-2.36) mm. That is, from fine, medium to coarse particle size. Therefore, the uniform coefficient (C_u) and coefficient of curvature (C_C) assessments of the soil particles range from 8 to 6, and 1. Under the Unified Soil Classification System (USCS, 2006), C_u greater than 4 to 6 classifies the soil as well graded, whereas, C_u less than 4 classifies it as poorly graded soil. Moreover, for the soil to be well graded, the value of C_C must range between 1 and 3. Hence, the samples were classified as well-graded. On the other hand, employing the (AASHTO, 2000) system of soil classification, the inorganic soil sample acquired was grouped into A-1, Subgroups into A-1-B, and A-2-4 constituting 50% and 29.1% significant material, rating the subgrade sample as excellent to good material suitable for construction works.

13. CONCLUSION

The selections of acceptable borrow pits used as subgrade material plays a vital role while designing a road construction. Necessarily, this research evaluated the peculiar suitableness of utilizing borrowed pit soils collected from Ndon Ebom as subgrade materials for road construction at Victor Attach International Airport. Comparing the six subgrade samples to common standard indicated that the soil samples acquired can be energetically applied as well as graded subgrade materials, on account of the suited index and mechanical properties. Comparatively: based on AASHTO and USCS soil classification systems, the subgrade was analyzed and graded as excellent to a good formation for construction works. In addition, the prospective connotations of the current research are awful. It establishes the practicability of borrowing pits as subgrade material for road construction. However, recommendations are made, that adequate laboratory tests be carried out on borrowed pit material before being used as a subgrade for construction works, to know its strength and stability. Hence, subsurface geologists, engineers, and contractors working within the terrain should make use of the inferred laboratory data to construct a road that will stand the test of time. On the other hand, cleaving to the code of standard of the engineering career to sustain best works.

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ACTIVITY OF ^{222}Rn IN TAP WATER IN KIELCE COUNTY

AKTYWNOŚĆ ^{222}Rn W WODACH WODOCIĄGOWYCH W POWIECIE KIELECKIM

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A b s t r a c t

Radon is known as a radioactive element that dissolves easily in water. It is worth mentioning that it is available in all possible reservoirs. Its concentration cannot be measured directly but only from the emitted radiation. Investigations of ^{222}Rn activity in water in the Kielce district were subjected to three selected water intakes: Bolechowice, Kołomań and Wola Kopcowa. This type of research was conducted for the first time in the discussed area. The results were analyzed in detail in terms of acceptable concentrations. Next, it was determined whether the geological location of the intakes in question may have an impact on the amount of radon present in water from the water supply network.

Keywords: radon concentration, water quality, geological structure

S t r e s z c z e n i e

Radon znany jest jako pierwiastek promieniotwórczy, który łatwo rozpuszcza się w wodzie. Warto zaznaczyć, że dostępny jest we wszystkich możliwych zbiornikach. Jego stężenia nie da się zmierzyć bezpośrednio, a jedynie na podstawie emitowanego promieniowania. Badaniom aktywności ^{222}Rn w wodzie w powiecie kieleckim zostały poddane trzy wybrane ujęcia wód wodociągowych: Bolechowice, Kołomań oraz Wola Kopcowa. Tego typu badania prowadzone są po raz pierwszy na omawianym terenie. Wyniki zostały poddane szczegółowej analizie, m.in. pod kątem dopuszczalnych stężeń. Następnie ustalono, czy położenie geologiczne omawianych ujęć może mieć wpływ na ilość pojawiającego się w wodach sieci wodociągowych radonu.

Słowa kluczowe: stężenie radonu, jakość wody, struktura geologiczna

1. INTRODUCTION

Uranium, thorium and radium are always present in rocks and soils in smaller or larger amounts. During the emanation process radon produced by the decay of radium can enter the pore spaces of rocks and soils. Radon is a radioactive gas that occurs naturally in nature. A characteristic feature of this element is its invisibility (it cannot be seen or smelled). It is found in the soil from where it constantly gets into the atmosphere. Studies prove that it is present in various amounts in households in the air and also in water [1]. Increased amounts of radon are observed mainly in areas where shale and granite rocks are found. As a noble gas, radon has a low binding capacity with solids, which is one of the reasons why it comes out of rocks. If we are dealing with places where rocks are predominant in the landscape, radon will get from them into the air and also into groundwater. So one should be aware of radon hazard in any place that is mountainous [2, 3].

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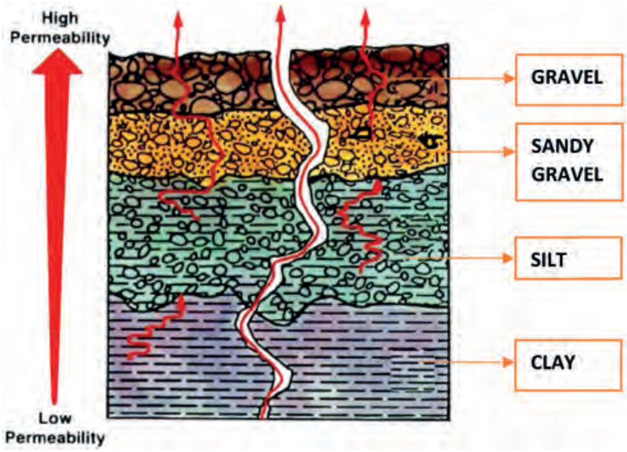

Fig. 1. Permeability of different geological formations [4]

Figure 1 shows the permeability of various geological formations. The ease and efficiency with which radon moves through pore space, including faults, exterminate how much radon will get into, for example, buildings, and tap water. The rate at which radon will penetrate soils depends on the soil's moisture content (how much water is contained in the pore space), porosity, and permeability (the soil's ability to transport water and air).

Radon is formed by the decay of uranium ^{238}U and thorium ^{232}Th. The geological structure and the concentration of uranium and thorium in the rock media are the main factors influencing radon emissions. The main carriers of uranium and thorium in magmatic rocks are accessory minerals such as monazite and xenotime. These minerals are resistant to weathering, hence they sometimes form quite rich accumulations in beach sandstones and scatters. The content of radioactive elements in rocks and the influence of tectonics on the possibility of their migration or penetration are the 2 main factors influencing the amount of radon emission.

Radon moves more slowly in water than in air. Up to the moment of decay, radon penetrates no more than about 2.5 cm in moist rocks or soils and up to about 180 cm in dry rocks. It is worth noting that water moves more slowly through pores in soil and faults in rocks, so radon travels shorter distances in moist geological formations before decaying [5].

The studies are aimed at determining whether water supplied to apartments in the in the Kielce district may be a source of radon hazard.

Additionally, the content of various substances indicating the quality of water was analysed, i.e. pH, conductivity, total hardness, chlorides, nitrites, nitrates, ammonium ions, phosphates, oxidisability and iron.

2. GEOLOGICAL STRUCTURE OF SELECTED SETTLEMENTS IN KIELCE COUNTY

Geologic structure is primarily the type of rocks, their age, and their mutual position in the earth's crust. Bolechowice, as shown in Figure 3, is mainly the remains of the Cretaceous (carbonate-siliceous rocks) and Jurassic, where the most calcareous rocks were formed. Kolomań is Wola Kopcowa is a mixture of Devonian (conglomerates and sandstones) and Silurian (limestone rocks, which today contain animal fossils) [6]. In the case of the Bolechowice and Wola Kopcowa intakes, the Middle Devonian is the geological layer from which water is drawn, whereas in the case of the Kołomań intake, it is the Triassic.

The villages of Bolechowice, Kołomań and Wola Kopcowa are above all the Świętokrzyskie Mountains, whose geological substrate is very rich. Their history covers 540 million years. It is worth noting that they have not always been mountains or land, and additionally it can be added that their location on the globe was not identical to the present one either. The oldest rocks found in the area of Świetokrzyskie Mountains are Cambrian rocks, available in many places, e.g. in Łysogóry. Ordovician and Silurian rocks are found mainly in Mycza, but also in various points of northern Kielce. Devonian for the Świętokrzyskie Mountains range was originally a terrestrial period. Silurian greywackes and the Lower Devonian conglomerates covering them are still visible, for example, in the Prągowiec Gorge. The upper part of the Devonian is again the sea (it reaches the maximum depth in the Carboniferous) where coral reefs developed. Rocks from this period include the Kadzielnia hills. Carboniferous movements are also called Hercynian or Variscan. The Świętokrzyskie region becomes land for millions of years.

It is worth noting that the current shape of the Świętokrzyskie Mountains is mainly the remains of movements during this period. The Permian, Triassic, Jurassic and Cretaceous rocks have unconformable positions on the folded rocks which can be seen in the quarry in Zagnańsk [7, 8]. Figure 2 shows angular and structural unconformities (Lower Triassic rocks lie on Middle Devonian dolomites).

Then we observe transgressions and regressions of the sea in the Upper Permian, Middle Triassic, Middle and Upper Jurassic, and the Upper Cretaceous leaving the Permian-Mesozoic margin of the Świętokrzyskie Mountains, complexes of weathering-resistant rocks, red sandstones of the Lower Triassic, and fossil dunes that can be seen in Tumlin.

Fig. 2. Quarry near Zagnańsk [9]

The sea in the area in question recedes with the end of the Jurassic, the Mesozoic era is mainly block movements. Paleogene and Neogene are the processes of weathering and denudation leading to the formation of the morphological equilibrium surface which becomes the starting point for the modern sculpture. The developing karst phenomena lead to the creation of caves with very phenomenal dripstone decoration. The best known is the Paradise Cave.

The Quaternary is the time of glaciations. On the ridges of hills there is strong mechanical weathering of exposed Paleozoic and Mesozoic rocks. Leading to the formation of the so-called gołoborza. A place very characteristic of the Świętokrzyskie Mountains [10, 11].

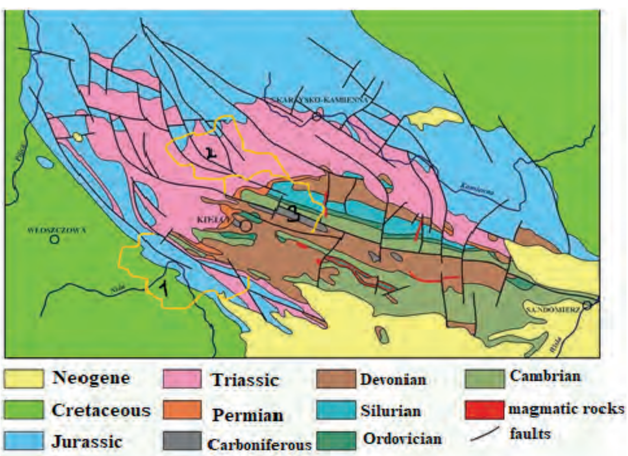

Fig. 3. Geological structure of the Świętokrzyskie Province with Bolechowice, Kołomań and Wola Kopcowa as particular locations [12]

The above figure shows the geological structure of the Świętokrzyskie province where Jurassic and Cretaceous remains are predominant. The surveyed intakes are presented numerically on the figure, where one is Bolechowice (dominance of Jurassic and Cretaceous); two is Kołomań (dominance of Triassic); three is Wola Kopcowa (mixture of Jurassic, Cambrian and Carboniferous, among others). Numerous faults appear in the studied areas, which translates into the movement of radon.

Table 1. Concentration of uranium and radium in rocks [13]

Rock type	Uranium [g/t]	^{226}Ra [Bq/kg]
Sands	0.45	1-27
Clay	1.8	77-124.1
Limestones	2.2	27.8
Granites	3	59.2
Bazslts	1	11.4
Phosphates	100-200 max 650	490

Table 2. Water quality parameters [14]

Water quality parameters	Permissible values
pH	6.5-9.5
Conductivity	2500 µS/cm
Total hardness	60-500 mg/dm^3
Chlorines	250 mg/dm^3
Phosphates	<5 mg/dm^3
Ammonium ion	0.50 mg/dm^3
Nitrates	50 mg/dm^3
Nitrites	0.5 mg/dm^3

2.1. Bolechowice

Bolechowice is located in the commune of Nowiny. This area is located within the south-western fragment of the Świętokrzyskie anticlinorium. Two main structural elements can be distinguished here: the Paleozoic core and its Permian-Mesozoic margin. As far as the Paleozoic structure is concerned, it has a folded structure and is strongly dislocated. The Branchzicko-Bolechowicko-Borkowska syncline consists of carbonate rocks of the Middle Devonian (limestone, dolomite). The core of the syncline is filled with rocks of the Upper Devonian (limestone, shale); Carboniferous rocks (claystones, shales, siltstones) and Permian (conglomerates, sandstones, siltstones, limestones). The syncline floor itself is mainly folded Lower Cambrian rocks (siltstones, sandstones, mudstones) [15].

2.2. Kołomań

Kołomań is located in the Zagnańsk municipality. This municipality includes its borders: the southwestern part of the Suchedniowski Plateau and the northern part of the Massif of the Holy Cross Mountains. As far as the structure is concerned, the Plateau is formed by the Lower Triassic sandstones, the so-called Pstry sandstones. There are also outcrops of limestone and marly dolomite, as well as small and sparse dunes. Referring to the geology of the substrate, the Zagnańsk commune is located within the Mesozoic shield of the Paleozoic core of the Świętokrzyskie Mountains, the structure of which consists of Permian and Triassic formations developed in the form of sandstones and limestones. The southern part of the community includes older formations of the Palaeozoic core of the Holy Cross Mountains, composed of Cambrian, Silurian and Devonian sediments. The Paleozoic is represented by Tsąpiascoides, Middle Cambrian and Upper Cambrian schists building the Krzemionki Mountains; quartzitic sandstones, siltstones and claystones (Barcza Mountain), as well as Middle Devonian dolomites (Góra Chełmowa). The Triassic formations (of the mottled sandstone) occupy the largest part of the municipality forming massifs of hills in the central, southern and western part of Zagnańsk. In these areas there are also thin and thick-bedded grey sandstones which may have a light grey shade; sandstones and siltstones, brittle, sometimes having a greyish-purple shade with mica, interlayered with slates known from the dolomite quarry. We are dealing here with Quaternary sediments such as: sands, clays, loess, silts, and also peats appearing mainly in the vicinity of the rivers, and also cover the whole commune in irregular patches. These are sediments of glacial, water-glacial, fluvial, aeolian, weathered (with fragments of bedrock) and deluvial origin [16, 17].

2.3. Wola Kopcowa

Wola Kopcowa is located in the Masłów Commune within the Paleozoic core of the Świętokrzyskie Mountains. Cambrian quartzite sandstones and quartzite and clay shales are the oldest formations. The Ordovician and Silurian represent sandstones, shales, and greywackes. Devonian is mainly carbonate sediments, dolomite, limestone and marl. Siliceous shales and claystones are the remains of the Carboniferous. The Permian is characterized by the remaining conglomerates and limestones. Quaternary sediments lie on top of the Palaeozoic basement and form a discontinuous cover of various shapes (clays, silts, gravels, sands, loess, peats and muds). As for the minerals occurring in the area, they are mainly sandstones, limestones, clay raw materials, sandstones and conglomerates. As far as economy is concerned, the greatest benefits are derived from Cambrian quartzitic sandstones (used as road aggregate and refractory material), which are mined from Wiśniówka deposit. In terms of obtaining other raw materials in the area of Masłów commune, it is visible that they are not fully exploited because of restrictions e.g. from the Świętokrzyski National Park. Due to the agricultural and tourist character of the commune, the development of the stone mining industry is not planned at the moment [18].

3. TEST METHODOLOGY

The first very important thing to study radon activity in water is proper sampling. Water was taken into 1.5l PET bottles after it had been slowly drained from the tap. For all studied intakes, both in January and February, water was taken after 4 min of slow flow from the tap. The water was poured full (under the stopper) to prevent the formation of air bubbles. Investigations of ^{222}Rn activity in water are performed using specialized equipment AquaKIT (manufactured by Genitron GmbH), which is connected to the AlphaGUARD PQ200PRO ionization chamber shown in Figure 4. To obtain correct results it must be remembered that half-life of radon – ^{222}Rn is only 3.825 days. Therefore, the collected water sample must be sent to the laboratory as soon as possible. Water in the water supply system was taken for measurement of radon activity after 4 min of free flowing. Three samples were taken from three different intakes in Kielce district (Bolechowice, Kołomań, Wola Kopcowa) in 1.5 l PET bottles. The samples were taken from 3 points on the intake of water supply network (initial middle and final).

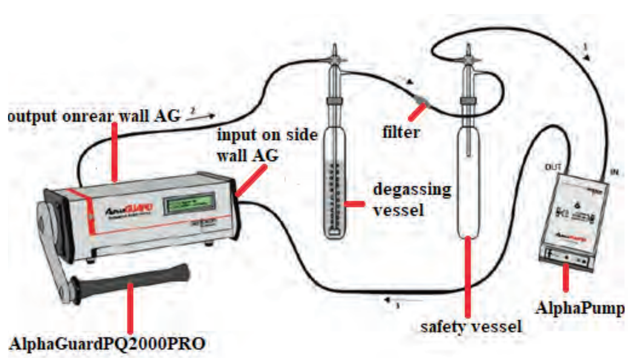

Fig. 4. Kit for measuring ^{222}Rn concentration in water samples [19]

The kit used to measure the concentration of ^{222}Rn in water samples, shown in Figure 1, consist of with a portable radon monitor (AlphaGUARDTM); a gas-tight pump with a step-regulated gas flow from 0.03 to 1.0 dm^3·min^{-1} (AlphaPUMPTM); and a gas-tight kit for degassing the water sample and, most importantly, for releasing the radon dissolved in it. The above-mentioned components are connected in a hermetically sealed circuit. The measuring station also includes an immersion thermometer (measures the temperature of the water at the time of the measurement being performed); a stopwatch that measures the exact time of the measurement; a „docker" (thanks to it, it is possible to incorporate a syringe with the collected water sample into the system, as well as a syringe that is part of the AquaKITTM set with a volume of 100 cm^3. Thanks to the connection of the AlphaGUARDTM monitor with a computer, all the data from the measurement are sent and collected and then the necessary calculations are made. This monitor is the basic fundamental device found on the test bench, as it performs the actual measurement of ^{222}Rn concentration. The measurement takes place in an ionization chamber equipped with filters that retain radioactive radon decay products, as well as impurities. Radon enters the chamber along with atmospheric air thanks to the AlphaPUMPTM pump. Before entering the chamber, the air is pumped through a glass vessel designed to degas the water sample, followed by an assurance vessel, also called a desiccant, where excess moisture is retained there is a possibility of condensation (this protects the ionization chamber from damage). The water sample under test is placed directly into the degassing vessel by connecting the syringe outlet to the „docker" and gently injecting the water, in such a way as not to cause turbulent flow, which could cause partial escape of radon. Immediately after injecting a 100 cm^3 water sample into the degassing vessel, the valves in this vessel and in the assurance vessel are closed to hermetically seal the measurement system. After transferring the water sample with a volume of 100 cm^3 into the measuring system and its hermetic closure, and turning on the AlphaGUARD™ in a one-minute measurement cycle, in flow mode, the actual measurement of radon concentration in the water sample, actually in the air of the ionization chamber, into which ^{222}Rn has been extracted from the water, takes place. During the first 10 minutes of the measurement, the AlphaPUMP™ works by pumping 0.30 dm^3·min^{-1} of air in a closed circuit: AlphaPUMP™-AlphaGUARD™-AquaKIT™. After 10 minutes of measurement, the pump is turned off and measurements continue, for another 20 minutes. After 30 minutes from the start of the measurement (turning on the pump), AlphaGUARD™ is turned off, ending the measurement. AlphaEXPERT™ software is used during processing of the obtained data. In this program, it is also possible to preprocess the data, including reading the average values of ^{222}Rn concentration and uncertainty of its determination for each 30-minute measurement. The average ^{222}Rn concentration along with the uncertainty of the determination is given in Bq/L. Conversion of this value to the concentration of ^{222}Rn in a water sample is possible using an equation proposed by the kit manufacturer [20, 21].

The water was additionally tested for pH, conductivity, total hardness, chloride, phosphate, ammonium ion, nitrate, and nitrite. These tests were carried out in the laboratory. The pH was measured with an Elmetron CP-551 pH meter. Conductivity was measured with a Hanna HI 8819 conductivity meter. Total hardness was measured by titration with disodium stannate. Chlorides were measured by the MOHRA method. Phosphate, ammonium ion and nitrite were measured by the calorimetric method. Nitrates were measured by the calorimetric method with phenolydisulfonic acid.

The results made it possible to determine the quality of water in a given locality.

4. RESULTS

Figures 5 and 6 summarize the results of ^{222}Rn activity in water for the Bolechowice, Kołomań, and Wola Kopcowa intakes.

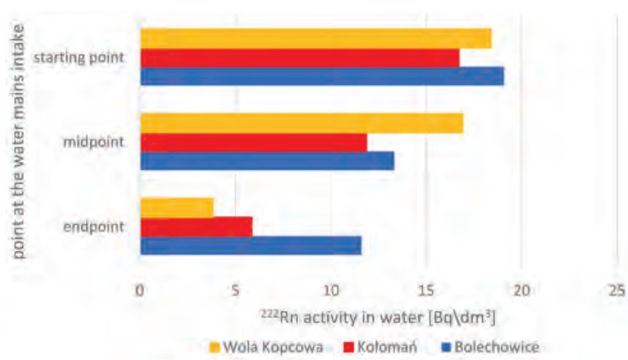

Fig. 5. ^{222}Rn activity in water for selected points at the intake during January

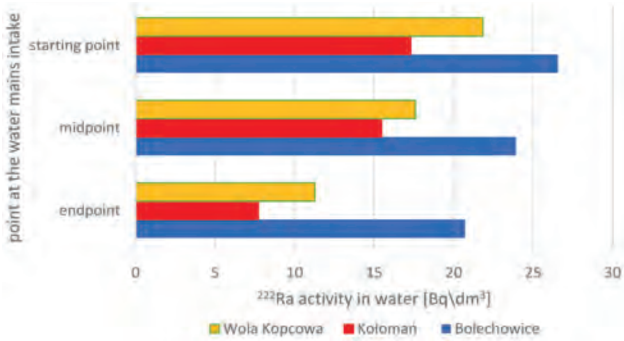

Fig. 6. ^{222}Rn activity in water for selected points at the intake during February

In January, average concentration of ^{222}Rn in water at the Bolechowice intake was 14.66 Bq/dm^3; for the Kołomań intake – 11.48 Bq/dm^3 and for the Wola Kopcowa intake – 13.04 Bq/dm^3. We observed that ^{222}Rn concentration in water is the highest at the beginning of the intake, with values decreasing in further sections. The highest concentration was recorded at Bolechowice intake – 19.06 Bq/dm^3 (beginning of intake). The lowest – 3.84 Bq/dm^3 was recorded in Wola Kopcowa (end of intake).

Table 3. Summary of water quality indicators for the Bolechowice intake in January and February

Index	Endpoint		Midpoint		Starting point	
	01.22.	02.22.	01.22.	02.22.	01.22.	02.22.
pH	6.40	6.41	6.80	6.37	6.40	6.47
total hardness [mg $CaCO_3$/L]	273.26	410.78	405.42	392.92	692.97	276.83
chlorides [mg/dm^3]	35.00	12.00	32.00	12.00	37.00	40.00
conductivity [mS]	0.62	0.34	0.90	0.64	0.64	0.63
phosporates [mg/dm^3]	0.15	0.28	0.11	0.03	0.14	0.05
ammonium ion [mg/dm^3]	0.03	0.30	0.20	0.30	0.00	0.30
nitrites [mg/dm^3]	0.010	0.010	0.010	0.001	0.004	0.010
nitrates [mg/dm^3]	15.23	17.02	4.43	4.13	7.61	6.21

Table 4. Summary of water quality indicators for the Kołomań intake in January and February

Index	Endpoint		Midpoint		Starting point	
	01.22.	02.22.	01.22.	02.22.	01.22.	02.22.
pH	6.40	6.72	6.40	6.60	6.30	6.52
total hardness [mg [$CaCO_3$/L]	367.92	357.20	453.64	285.76	128.59	142.88
chlorides [mg/dm^3]	15.00	12.00	13.00	13.00	16.00	13.00
conductivity [mS]	0.35	0.40	0.34	0.35	0.31	0.36
phosporates [mg/dm^3]	0.09	0.06	0.15	0.23	0.12	0.15
ammonium ion [mg/dm^3]	0.00	0,30	0.00	0,69	0,40	0.50
nitrites [mg/dm^3]	0.003	0.004	0.006	0.001	0.020	0.001
nitrates [mg/dm^3]	6.55	5.92	10.52	10.08	17.18	18.03

Table 5. Summary of water quality indicators for the Wola Kopcowa intake in January and February

Index	Endpoint		Midpoint		Starting point	
	01.22.	02.22.	01.22.	02.22.	01.22.	02.22.
pH	6.50	7.96	7.40	8.00	6.30	7.23
total hardness [mg $CaCO_3$/L]	292.90	267.90	23.22	375.06	528.66	500.08
chlorides [mg/dm^3]	12.00	15.00	12.00	15.00	39.00	41.00
conductivity [mS]	0.62	0.73	0.56	0.64	0.63	0.71
phosporates [mg/dm^3]	0.06	0.05	0.12	0.09	0.16	0.06
ammonium ion [mg/dm^3]	0.10	0.30	0.06	0.50	0.04	0.30
nitrites [mg/dm^3]	0.002	0.010	0.010	0.001	0.200	0.001
nitrates [mg/dm^3]	3.36	4.16	15.05	14.89	13.28	13.48

In February, mean concentration of ^{222}Rn in water at the Bolechowice intake was 23.73 Bq/dm^3; for the Kołomań intake – 13.49 Bq/dm^3 and for the Wola Kopcowa intake – 16.9 Bq/dm^3. We observe that ^{222}Rn concentration in water is the highest at the beginning of the intake, with values decreasing in further sections. The highest concentration was again recorded at Bolechowice intake – 26.55 Bq/dm^3 (beginning of intake). The lowest concentration of 7.71 Bq/dm^3 was recorded in Kolomani (end of intake).

Tables 3-5 present results of selected quality indicators for water from Bolechowice, Kołomań and Wola Kopcowa intakes. Similarly to the studies on radon activity, water was taken from 3 points in the water supply network. For the Bolechowice intake, the pH value is usually slightly lower than recommended for human consumption, where the lower limit is 6.5. For the Kołomań intake, the range is 6.3 to 6.72. For the Wola Kopcowa intake, the range is 6.5 to 8.0 (the water has the best pH compared with the others). Total hardness was exceeded for the Bolechowice intake in January, at the beginning of the network, but in the next analyzed month a significant decrease can be observed, which is within the permissible ranges of values. The situation is similar for the Wola Kopcowa intake. The other analysed water quality indicators, i.e. chlorides, phosphates, ammonium ions, nitrites and nitrates, occur in small quantities which do not impair the water quality at all. The values of conductivity are within the range for drinking water.

5. CONCLUSIONS

The Bolechowice, Kołomań and Wola Kopcowa intakes under study are located in picturesque areas of the Świętokrzyskie Mountains. Hence, their geological structure is quite rich and the occurrence of various raw materials and minerals is connected with it. Bolechowice is mainly remains of Jurassic and Cretaceous (limestone rocks, carbonate-silicate rocks). Kołomań is Triassic (red sandstones – claystones). And Wola Kopcowa is Jurassic and Cambrian (limestone rocks, conglomerates and sandstones). As far as the geological layers the water is drawn from are concerned, for Bolechowice and Wola Kopcowa it is Middle Devonian, while for the Kołomań intake it is Triassic.

Radon is released from the ground mainly to the air by emanation i.e. release of radon from grains of rocks and minerals; transport i.e. migration of released radon in a given space and exhalation i.e. release of this element from soil and various minerals. The fact that it dissolves well in water may be a reason for radon transport to much further distances from its origin.

Water quality tests carried out for the intakes in January and February showed that the pH of the Bolechowice intake is quite low, but acceptable for drinking water. Total hardness, chlorides, conductivity, phosphates, ammonium ion, nitrites and nitrates are within permissible concentrations for water intended for human consumption. After analyzing all the results it can be concluded that the water is of very good quality.

Preliminary studies of radon activity in water show its presence. This indicates that the minerals present are conducive to the migration of this radioactive element into water.

According to WHO, the highest permissible concentration of ^{222}Rn in water intended for consumption is 100 Bq/dm^3, however in literature one can find more drastic restrictions which allow only 15 Bq/dm^3. It is worth noting that we rarely consume water directly from the tap. Filtered water loses many minerals and radon migrates from it to the air. Water after boiling will be free of radon. The amount of this element in water is trace so it should not have a negative impact on human health and life.

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CASE STUDY OF THERMAL COMFORT, LIGHTING CONDITIONS AND PRODUCTIVITY AT TWO CLASSROOMS OF POZNAŃ UNIVERSITY OF TECHNOLOGY

STUDIUM PRZYPADKU KOMFORTU CIEPLNEGO, OŚWIETLENIA I PRODUKTYWNOŚCI W DWÓCH SALACH DYDAKTYCZNYCH POLITECHNIKI POZNAŃSKIEJ

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Abstract

The papers analyses subjective sensations of thermal comfort, lighting conditions and self-reported productivity of 51 students of Poznań Univeristy of Technology (Poland). The study took place in the spring and was based on the use of anonymous questionnaires with questions on thermal sensations, acceptability and preferences as well as the students' assessment of their current productivity and lighting conditions. The test results indicate that the overwhelming majority was satisfied with thermal environment and lighting conditions in the rooms. Their general sensations were also largely positive, while self – reported productivity was generally assessed to be normal.

Streszczenie

Artykuł analizuje subiektywne odczucia komfortu cieplnego, warunków oświetleniowych oraz produktywności 51 studentów Politechniki Poznańskiej. Badanie odbyło się wiosną i opierało się na wykorzystaniu anonimowych kwestionariuszy z pytaniami o odczucia cieplne, akceptowalność i preferencje oraz ocenę przez studentów aktualnej produktywności i warunków oświetleniowych. Wyniki badań wskazują, że zdecydowana większość była zadowolona z warunków termicznych i oświetlenia w pomieszczeniach. Ich ogólne odczucia były również w dużej mierze pozytywne, podczas gdy produktywność została ogólnie oceniona jako normalna.

GEOTECHNICAL INVESTIGATION OF BORROW PIT AS A SUBGRADE MATERIAL FOR ROAD CONSTRUCTION AT VICTOR ATTAH INTERNATIONAL AIRPORT, UYO, NIGERIA

BADANIE GEOTECHNICZNE MATERIAŁU Z WYKOPU JAKO PODŁOŻA DO BUDOWY DRÓG NA MIĘDZYNARODOWYM LOTNISKU VICTOR ATTAH UYO NIGERIA

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Abstract

One of the mass prompt practices of soils is for engineering projects such as the construction of roads, buildings, dams, and so on. Therefore, it needs to investigate its suitableness of index and mechanical properties. This study aims to determine the essential quality material required for road construction, thereby poses détente prospect for the disposal of ineffectual atrophy generated on sites. Such materials are classified into index and mechanical properties. Six subgrade samples were taken at the depth to bottom ranging from (1.0-5.0) m and tested. The sample was subdued to the laboratory tests, such as Sieve Analysis, Atterberg limits, compaction, California Bearing Ratio (CBR), and Specific Gravity (SG) respectively. The mechanical analysis which involved particle size distribution revealed that the subgrade was finely grated with a limit of ≤35% for subgrade passing sieve No. 200 (0.075 mm) with 29.1%, with an average Natural Moist Content (NMC) of 13.9%. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were 1.83 mg/m³ and 11.5%. The index analysis involved the liquid and plastic limits determination of Liquid Limit (LL) of 35.8%, Plastic Limit (PL) of 24.0%, and a Plasticity Index (PI) of 12%. California Bearing Ratio (CBR) results were 20.3% (soaked). The SG test results ranged from (2.68-2.94) kg/m³, employing the American Association of State Highway and Transport Officials (AASHTO) system of soil classification. The AASHTO grouped the materials into A-1, subgroups A-1-b and A-2-4 constituting 50% and 29.1%, with significant materials composed of stone fragments and sand rating the subgrade samples as excellent to good materials suitable for road construction.

Streszczenie

Jedną z masowych praktyk związanych z gruntami są projekty inżynieryjne, takie jak budowa dróg, budynków, zapór itp. Dlatego należy zbadać przydatność gruntu i jego właściwości mechaniczne. Niniejsze badanie ma na celu określenie niezbędnych właściwości materiału wysokiej jakości wymaganego do budowy dróg, co stwarza perspektywę usunięcia nieefektywnych wykopów generowanych na terenie. Materiały są klasyfikowane według wskaźników i właściwości mechanicznych. Sześć próbek gruntu pobrano z głębokości w zakresie 1,0-5,0 m i poddano badaniom. Próbki zostały poddane testom laboratoryjnym, takim jak analiza sitowa, granice Atterberga, zagęszczenie, kalifornijski wskaźnik nośności (CBR) i ciężar właściwy szkieletu gruntowego (G_S). Analiza rozkładu wielkości cząstek wykazała, że grunt był drobnoziarnisty o uziarnieniu ≤35% dla sita nr 200 (0,075 mm) oraz 29,1%, przy średniej naturalnej wilgotności gruntu (W) wynoszącej 13,9%. Maksymalna gęstość szkieletu gruntowego (ρds) i optymalna zawartość wilgoci (Wopt) wyniosły odpowiednio 1,83 mg/m³ i 11,5%. Wyznaczono granice płynności i plastyczności: granica płynności (wL) wynosiła 35,8%, a granica plastyczności (wp) 24,0% oraz wskaźnik plastyczności (Ip) na poziomie 12%.

Kalifornijski wskaźnik nośności (CBR) wyniósł 20,3% (po nasiąkliwości). Wyniki badań G_S wahały się od 2,68 do 2,94 kg/m³, przy zastosowaniu systemu klasyfikacji gruntów AASHTO. Według AASHTO pogrupowano grunty na A-1, podgrupy A-1-b i A-2-4 stanowiące 50% i 29,1%, przy czym materiały składające się z odłamków kamieni i piasku oceniono jako doskonałe lub dobre materiały nadające się na budowy dróg.

ACTIVITY OF ^{222}RN IN TAP WATER IN KIELCE COUNTY

AKTYWNOŚĆ ^{222}RN W WODACH WODOCIĄGOWYCH W POWIECIE KIELECKIM

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Structure and Environment vol. 14, No. 2/2022, p. 55 DOI: 10.30540/sae-2022-007

Abstract

Radon is known as a radioactive element that dissolves easily in water. It is worth mentioning that it is available in all possible reservoirs. Its concentration cannot be measured directly but only from the emitted radiation. Investigations of ^{222}Rn activity in water in the Kielce district were subjected to three selected water intakes: Bolechowice, Kołomań and Wola Kopcowa. This type of research was conducted for the first time in the discussed area. The results were analyzed in detail in terms of acceptable concentrations. Next, it was determined whether the geological location of the intakes in question may have an impact on the amount of radon present in water from the water supply network.

Streszczenie

Radon znany jest jako pierwiastek promieniotwórczy, który łatwo rozpuszcza się w wodzie. Warto zaznaczyć, że dostępny jest we wszystkich możliwych zbiornikach. Jego stężenia nie da się zmierzyć bezpośrednio, a jedynie na podstawie emitowanego promieniowania. Badaniom aktywności ^{222}Rn w wodzie w powiecie kieleckim zostały poddane trzy wybrane ujęcia wód wodociągowych: Bolechowice, Kołomań oraz Wola Kopcowa. Tego typu badania prowadzone są po raz pierwszy na omawianym terenie. Wyniki zostały poddane szczegółowej analizie, m.in. pod kątem dopuszczalnych stężeń. Następnie ustalono, czy położenie geologiczne omawianych ujęć może mieć wpływ na ilość pojawiającego się w wodach sieci wodociągowych radonu.

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