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ANALYSIS OF SULPHATE IN WASTE SOIL FOR CONSTRUCTION: A CASE STUDY OF GOODYEAR DEVELOPMENT SITE, ENGLAND

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Abstract

The study examines sulphate in the excavated waste soil for construction in Goodyear Development Site in England. The aim is to determine whether the sulphate in the soil is concentrated in high level as to pose risk to soil stabilization, roads construction, building foundation, landscape work, human health and the environment. In this research, a qualitative approach was adopted. In-situ test was carried out by adoption of olfactory method while intrusive approach X-ray fluorescence spectrometry was used to generate data. An olfactory soil test was carried in-situ to determine the presence of hydrogen sulphide. The olfactory soil test indicated absence of hydrogen sulphide because there was no smell of rotten-egg nor sweetish odour. Further investigation of soil samples from Goodyear Development Site was carried out at University of Wolverhampton in West Midlands, England laboratory. The results reveal that the pH value is 7.7 which indicate alkaline. The sulphate content value in the studied area is 0.2% or 224.4 ppm by weight of soil which is within the threshold considered nonhazardous and insignificant to pose threat to soil stabilization, road construction, land degradation, landscape work, human health and the environment. Thus, the sulphate value collaborates with the U.S. Department of Transport guidelines for sulphate assessment. The study, therefore, concludes that the soil is satisfactory for Goodyear Development Site. Hence, recommends that similar study be carried out on waste soil excavated for use in constructions works and development sites to determine the concentration of its mineral contents particularly sulphate content level to ensure safety of soil stabilization on construction works, development sites, human health safety and the environment.

Keywords: Sulphate Concentration, Soil Stabilization, Development Site, Waste soil, X-ray Fluorescence Spectrometry.

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1. Introduction

Basically, soil physical and chemical properties are vital component for consideration in construction works and development sites to avoid harm to plant and animal life, stabilized soil, land degradation, buildings foundations, roads construction and other infrastructures. However, high sulphate (SO_4^{2-}) concentration in the soil affects adversely. Waste soil refers to excavated topsoil or subsoil that either involves treatment before additional useor it is not required for use at its site of production, while Greenfield soil is excavated from undeveloped site and used at the same site, it is not deemed to be contaminated for use in construction and development site (Scotish Environmental Protection Agency, 2010). Sulphate mineral at high concentration has the capacity to induce negatively on stabilized material, human health and environment. In geotechnical projects, adverse soil bearing capacity problems are solved through removal and replacement soil in situ, reclamation and reuse of waste or contaminated soils to minimize site abandonment (Makusa, 2012). The use of waste soil or Greenfield soil has gained significance in construction for capping of roads, landscape work, and soil stabilization in recent times. For instance, soft soils such as silt, clayey peat, or organic soils are stabilized to meet the required civil engineering properties before construction site work takes place. The study became necessary in view of the fact that the substance of sulphate is abundant in the soil and has the potentials at high concentration to react with other minerals to degenerate to other hazardous compounds.

Furthermore, sulphate substance is the vital parameter to be considered when assessing soils as foundation material or for construction purposes (Pillai, Abraham, Sridharan, 2011; Makusa, 2012).However, the work of Longworth, (2004) points out that some of the micro structural damages are caused by sulphate attack in building foundations, capping layers to roads, hard standing to vehicles and other structures. Studies show that sulphate-rich soil attack and weaken the strength of stabilized materials. For instance, lime and cement used to stabilize soil from sulphate attack sometimes fail. Basically, calcium-base stabilizer react with sulphate-rich mineral to form calcium-aluminate-sulphate-hydrate (CASH) (ettringite) and (or) thamausite (Sherwood, 1993; Pillai, *et al.,* 2011, Makusa, 2012). It is further highlighted that oxidation of sulphide (iron pyrite (FeS2)) produces sulphuric acid which has the capacity to attack stabilized material. Several investigations have been carried out on distribution of sulphur (non-metal), sulphate and sulphide at high concentration produces an environmental concern because they undergo changes to transform to other compounds which cause human health hazards, land degradation, contamination of agricultural products, damage to infrastructure (building and road) and possible waterway (Longworth, 2004, Pillail *et al*., 2011; Makusa, 2012). Notable work by Ogeh, Uzu, and Obi-Ijeh (2012) admits that sulphur has the potentials to react with several cations to produce sulphide or sulphate that can change to sulphide under anaerobic conditions. The study stresses that the main source of sulphate soil is through decay contents and organic matter addition from plant, animal sources and inorganic fertilizer.

Indeed, it is therefore increasingly difficult to ignore the suspicion whether sulphate is hazardous or non-hazardous element to stabilized material, human health and environment. Contamination of the soil environment due to its chemical composition level has an unfavourable effect on physiochemical properties of the soil and this could reduce its protective function (Baronowski,

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Rybak, and Baranowska, 2002). Besides, anthropogenic activities relating to soil contamination have significant impact on human health and environment. However, this action is traceable to industrialization, and urbanization which resulted to soil adsorption of the heavy metals and metalloids that have negative impact on the environment.

Moreover, contamination exists in different aspects of environment at a site which encompasses soil, soil gas, ambient air, groundwater and surface water. Western Australia Department of Environment Regulation (2017) states that elements of environmental concern may be observable in the soil, liquid or gaseous state and thereby produces contaminated vapour. Waste soil sometimes produces colourless gas such as hydrogen Sulphide (H2SO4) at minimal concentration noticeable in respiratory system with unpleasant odour that smell like rotten-egg or sweetish smell (West Australia Department of Health n.d). Western Australia Department of Health (n.d) admits that hydrogen sulphide may pose health risk at much lower concentrations. Western Australia Department of Health (n.d) points out those human activities in the industries may produce hydrogen sulphide such as sewage treatment plant, piggeries, manure handling operations, waste soil movements and others. Consequently, hydrogen sulphide at the concentration of 0.008 ppm is odour threshold as well as the level of increasing possible irritation and headache.

Furthermore, USDOT states (Department of Transport, 2000) if sulphate concentration is below 0.3% or 3,000 parts per million (ppm), by weight of soil, its impact on human and the environment is not significant to cause harm. Again, if the total concentration of sulphate in the soil is between 0.3% (3,000 ppm) and 0.5% (5,000 ppm) it is moderate and do not constitute harm to the environment. When the total sulphate levels is between 0.5% (5,000 ppm) and 0.8% (8,000 ppm) it represents moderate to high risk. Add, when the sulphate concentration is greater than 0.8% (8,000 ppm) it represents high risk to human and the environment. Lastly, when the sulphate concentration is higher than 1.0% (10,000 ppm) generally they are not suitable for development site use because of the high risk of sulphate reaction that will result to damages of the site and environment.

This study was conducted at the Goodyear Dunlop Tyre and Rubber Company Development Site and the collected soil samples experiment took place at University of Wolverhampton laboratory, West-Midlands, England. Globally, the overarching question of waste soil safety on human health, soil stabilization, landscape degradation, road construction, farmlands destruction, and building foundation informs this study: Is sulphate content in the waste soil in Goodyear Development site significant or insignificant to pose threat to soil stabilization, road construction, land degradation, landscape work, human health and the environment? Besides, is the sulphate content value within the threshold acceptable by the U.S. Department of Transport guidelines for soil stabilization?

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Methodology

Description of the Study Area

Goodyear Dunlop Tyre and Rubber Company development Site delineated for workers accommodation, which is among the regeneration scheme to raise houses for the public under the control of Wolverhampton City Council (Express and Star News 2015). In 1927, the factory that situates on 88 acres was opened in Bushbury lane, approximately two miles North of Wolverhampton City Centre and it was finally sold off in 2002 and the site was handed over to developer St Modew (Express and Star News, 2016). Wolverhampton is a city and Metropolitan borough in the West Midlands, England. The study area lies within latitude $52^{o}35^{1}28.9320$"N and longitude 2^{o} 6 ^{1} 38.6928"W (LatLong.net, n.d). Goodyear development site situates in Wolverhampton as shown below in the diagram.

(Source: Express and Star News, 2015).

Figure 1: Study Area in Goodyear Development Site in Wolverhampton.

The above figure 1 is the location of the study area where Goodyear tyre company development site situates for their workers presently under the house scheme regulated by Wolverhampton City Council.

(Source: Study site photograph, 2013).

Figure 2: Study areas in Goodyear Development Site, 2013.

The above figure 2 is the photograph snapped at Goodyear tyre Company presently delineated to Wolverhampton City Council for building development. The photograph shows the excavated soil heap and fence made round it to safeguard against passer-by. Notice board placed in the area which regulates human movement within the protected area.

The execution of this study involved several tasks. These include collection of available primary and secondary and use of both in-situ and intrusive approaches to carry out the analysis. Firstly, an olfactory soil test was carried out in-situ to find out whether the waste soil hydrogen sulphate content concentration is noticeable at odour threshold level that pose risk to human health and environment.

Secondly, intrusive method was used to analyze the soil samples. Soil samples were collected in polythene bags and sealed immediately after collection before it was taken to the laboratory. The soil sulphate data was generated with the aid of X-Ray fluorescence Spectrometry.

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Furthermore, the accepted threshold level recognized as significant and insignificant by the government authority was also used as guideline to determine the sulphate threshold that can degenerate to hazardous effect on soil stabilization, road capping, building, human health and environment.

Experimental Procedures

Apparatus

The excavated soil samples were collected in June, 2013 from Goodyear Dunlop Tyre Company development site in Wolverhampton. The soil samples were examined with the aid of X-ray Fluorescence Spectrometry. Hand trowel, hand gloves, polythene bag were used at the field site. Grinding machine used for the experiment was set at the revolution of 45^o and at the temperature of 9^oc for 2 minutes. Hydraulic press called Graseby Specac was used to shape the soil samples to plate form. Weighing balance, sieves of different sizes, pestle and mortar, marking pen were used in the laboratory for identification. Besides, the team walked round the site to carry out olfactory test to detect the odour threshold in-situ for Hydrogen Sulphide existence at minimal perceptible concentration at 0.008ppm (West Australia Department of Health, n.d.).

Soil Sample

In the study areas, olfactory test was conducted while walking around the site and later some soil samples were collected and also tested in-situ using an olfactory soil testing method to determine whether the waste soil content contains hydrogen sulphide. The olfactory soil test procedure was adopted, and usually wherever hydrogen sulphide exists, instantly it is identifiable with the smell of rotten-egg or sweetish odour.

Test Programme

Sulphate content in the soil is usually measured in parts per million (ppm) and percentage. In this study, the results are presented in both part per million and in percentage. For instance, 10,000 ppm is equivalent to 1.0%. Hence, 2,000 ppm is equal to 0.2%. The sulphate content result is presented in dry weight which collaborates with U.S Department of Transport (U.S Department of Transport, 2000) report. Besides, the result presentation of this study is a prototype of the earlier works of Pillai, et al. (2011), that adopted US Department of Transport 2000 guidelines for result presentation.

Procedure

At Goodyear development site, soil boring was carried out at different point and at different depths about 25cm and 25cm where the heaped soil was packed with the aid of hand trowel. Six soil samples were collected at the site; each of the six soil packs was divided into four which gave rise to a total of twenty-four samples for the analyses. The soil samples were taken to the laboratory at University of Wolverhampton and it was left for three days to be air-dried under ambient temperature condition. Thereafter, the dried soil were gently disaggregated and sieved with different categories of sieves to remove stones, coarse materials and achieve uniform particles sizes based on the sieves used. Later, the soil samples were stored in polythene bags

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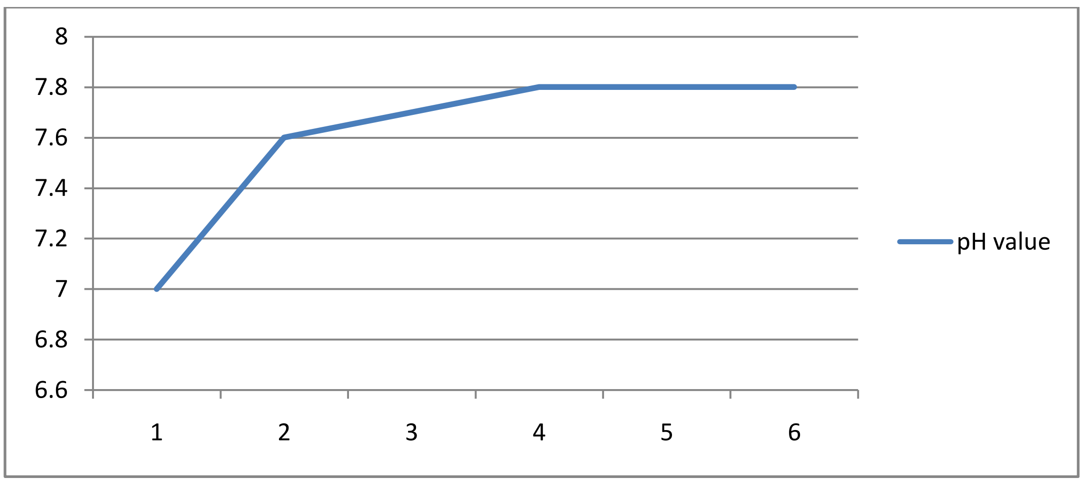
before analysis. The samples were spread in trays 2-3cm depth. Later, the samples were mixed to create homogeneity among the samples before subdivision. Furthermore, the six soil samples collected which were subdivided into 24 parts, where six samples measuring 10g each were separated for pH reading. The six samples for pH reading measured 10 grammes each were mixed with 100 ml of deioned water suspension. The soil pH was determined in potentiometric in deionized water with 100 ml. Another set of 6 samples of the soil were passed through the 2mm sieved and pelleted when it was mixed with wax at the ratio of 8.5 to 1.5 gramme. Each of the samples weighs 10 grammes. Another 6 samples were sieved to pass through 500 microns and they were grinded. Another 6 samples sieved 2mm were ungrounded. Finally, the eighteen soil samples were sent for X-ray Fluorescence spectrometry analysis. U.S. Environmental Protection Agency (EPA, 2007) approves the X-ray Fluorescence is suitable instrument for analysis of macro elements.

Results

The soil sample pH values were determined and values are in the figure 3 below:



(Source: Analysis of data, 2013).

Figure 3: Soil Samples pH values.

Figure 3 above shows the outcome of pH values of the soil samples collected from Goodyear Development Site. Six soil samples were used to test for pH values and the highest pH value is 7.8 while the lowest is 7. The outcome of the entire result of the samples is alkaline. The mean value of the samples is 7.7.

Sulphate concentration of the waste soil samples from Goodyear Development Site was analysed. The sulphate content values obtained from the samples with X-ray Fluorescence Spectrometry are illustrated in figure 4.

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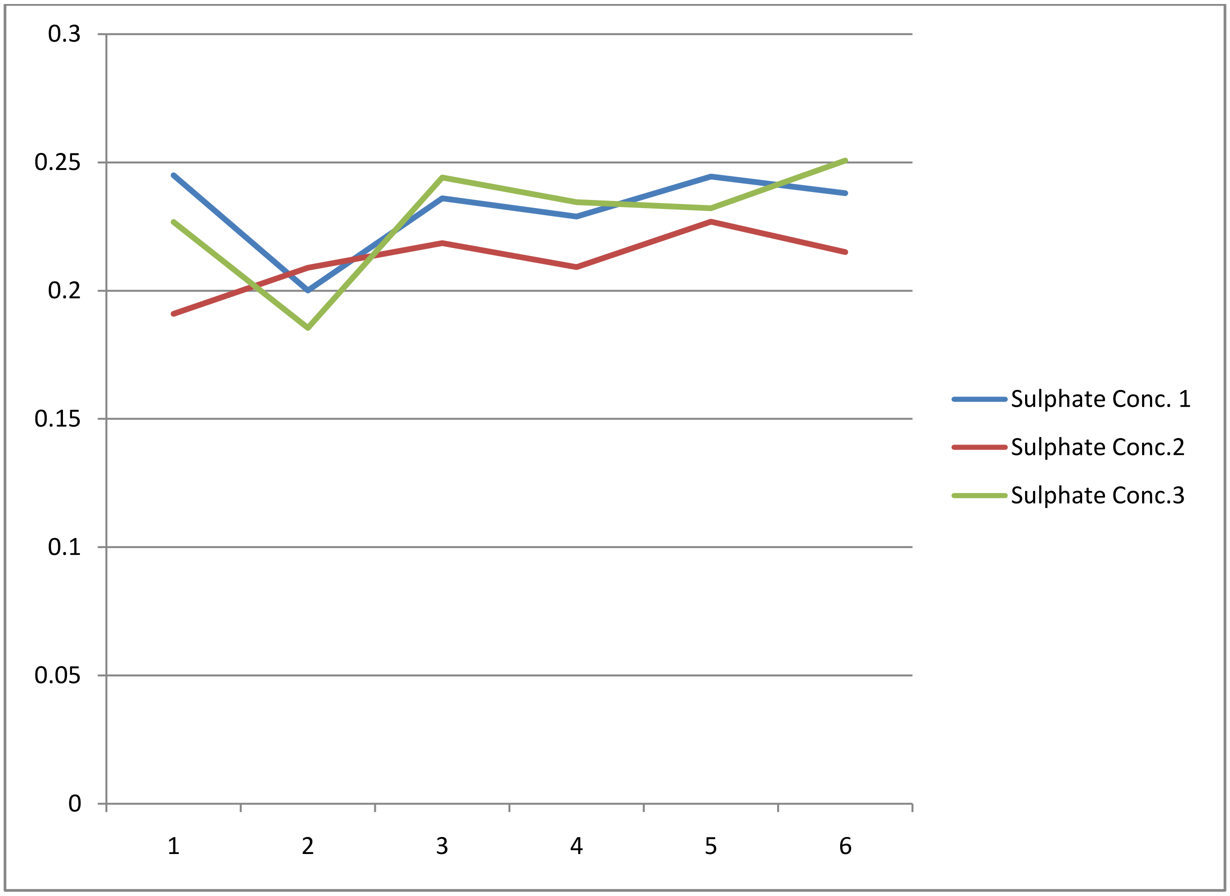

(Source: Analysis of data, 2013).

Figure 4: X-ray Results for the Sulphate

Figure 2 above shows the X-ray Fluorescence Spectrometry results of sulphates content in the soil in the study area. The said results are in percentages (%) and it is converted to parts per million by multiplication of the value by 10,000. The data sets of the three soil samples with each set contain six samples and the entire soil samples are eighteen. The graph above shows that the sulphate concentration fall between 0.9% to 0.25%. The mean concentration of sulphate content in the entire soil samples is 0.2% or 2241.779 ppm by weight of soil. The sulphate concentration in the Goodyear Development site is within the threshold value delineated as insignificant. This result collaborates with United States Department of Transport guidelines on nonhazardous threshold of sulphate concentration in the soil that is insignificant to pose hazard to human health and the environment. Therefore, the value of sulphate content is insignificant to degenerate to harmful compound.

Discussions

The olfactory test carried in-situ at Goodyear tyre development Site indicates the absence of hydrogen Sulphide because there was no smell of rotten-egg nor sweetish odour. The sulphate content value in the studied area is 0.2% which is within the threshold considered nonhazardous and insignificant to pose threat to soil stabilization, road construction, land degradation, landscape work, human health and the environment.

Conclusion

In the study area, sulphate content in the soil has been determined and the following conclusion has been reached.

Sulphate concentration of 0.2% is within the threshold considered as nonhazardous and insignificant react with other minerals to be vulnerable to soil stabilization, road construction, landscape, land degradation, human health and the environment. Besides, the olfactory soil test indicate absence of hydrogen sulphide because there was no smell of rotten-egg nor sweetish odour. Hence, Goodyear Development Site waste soil is proved satisfactory for use in the development site.

Recommendation

Based on the findings of this study, hence the following recommendations:

That similar study be carried out on waste soil collected for use in constructions works and development sites to determine the concentration of its mineral contents particularly sulphate content level to ensure safety of soil stabilization on construction works, human health safety and the environment.

Acknowledgement

The authors' special thanks go to Kerion Finney and other lecturers of University of Wolverhampton that contributed to the success of the master's degree programme within a recorded time frame. The figure below shows my University supervisor Kerion Finney when he accompanied me for the samples collection at Goodyear Dunlop Tyre Company Development Site.

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References

Baranowski, R., Rybak, A., and Baranowska, I. (2002) Speciation Analysis of Elements in Soil Samples by XRF. Polish Journal of Environmental Studies. 11(5) pp.473-482

Express and Star News (2015, May, 11) Extra 124 homes planned for Wolverhampton Goodyear Site. London. Retrieved from https://www.expressandstar.com/news/2015/05/11/extra-124-homes-at-wolverhamptons-goodyear-site/

Express and Star News (Dec 20, 2016) Goodyear closure: Wolverhampton factory shuts gates for last time after 89 years.https://www.expressandstar.com/business/midlands-business/2016/12/20/goodyear-closure-wolverhampton-factory-shuts-gates-for-last-time-after-89-years/

LatLong.net revisited (n.d) Wolverhampton, West Midlands, Geographic Information. Retrieved from https://www.latlong.net/place/wolverhampton-west-midlands-uk-3559.html

Longworth, I. (2004) Assessment of sulphate bearing ground forsoil stabilization for development. London: Civil Engineers

Makusa, G.P. (2012) Soil Stabilization Methods and Materials.State of Art Review. Lulea, Sweden: Lulea University of Technology.

Ogeh, J.S., Uzu, F., and Obi-Ijeh, O.D. (2012) Distribution of sulphur in soils formed from parent materials in Southern Nigeria. 20(1):73-77

Pillai, A.G., Abraham, B.M. and Sridharan, A. (2011) Determination of Sulphate Content in Marine Clays.International Journal of Engineering Research and Applications. 1(3) pp.1012-1016

Scotish Environmental Protection Agency (2010) Regulatory guidance promoting the sustainable reuse of greenfield soils in construction.

Sherwood, P. (1993) SoilStabilization with cement and lime.State of the Art Review. London: Transportation Research Laboratory, HMSO

U.S. Department of Transport (2000) Guidelines for stabilization of soils containing sulphate, Technical Memorandum, Texas: Department of Transport.

U.S. Environmental Agency (2007) Method 6200: Field portable X-ray Fluorescence Spectrometry for the determination of elemental concentrations in soil and sediment. United States: Environmental Agency.

Western Australia Department of Environment Regulation (2017) Identification, reporting and classification ofcontaminated sites in Western Australia: Contaminated Sites Guidelines. .Perth: Department of Environment Regulation

Western Australia Department of Health (n.d) Hydrogen Sulphide and public health. Perth: Department of Health.