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SOIL PROPERTIES FOR EARTH BUILDING CONSTRUCTION IN CITY OF ZAKHO-IRAQ

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Abstract: Earth is the most common and important building material used in construction industry as it found in almost every country in the world. Modern earth building is alive and well spread over an enormous geographical area using different earth materials and numerous methods of construction and has many benefits for construction and buildings. Zakho city, which is located in the south of Iraq, distinguished of its heritage earth architecture with many benefits and marvelous types and exterior views. Many weaknesses of the material, lake of knowledge and quick development caused lifting and destroying many of its mud and heritage building during the last few generations. Not all soils are suitable for every building need. Soil specification is very important to ensure that the materials used in construction meet all needs. Available locally material of common quality was taken from local site in Zakho city. Laboratory experimentation and testing was done to determine the properties of this material. Results were recorded for further studies and heritage building conversation and rehabilitation and for modern earth building material and techniques.

1 Introduction

Earth buildings spread around the world, as shown in figure1. Traditional construction uses available local materials for walled bearing construction earth. Characteristics of earth material can assume many important benefits like the very low cost, environment and energy saving [1, 2, 3,4]. Recently, the Iraq government increased its attention for tourist and historic culture and buildings. Many conservation and restoration projects had done and researches were also done in this area. Traditional buildings of Zakho city are distinguished of its heritage earth architecture with many benefits and marvellous types and exterior views (Fig.2). Earth buildings have drawbacks due to the economy situation and modern building. It has been cleared that classical earth building material and its techniques cannot fulfill the modern housing. Usually, soil mixed with additives or with imported materials to achieve suitable soil mix design for modern construction [5, 6].

Determination the most important properties of soil are very important to develop new mix and earth blocks to save the earth building heritage and continues material used.

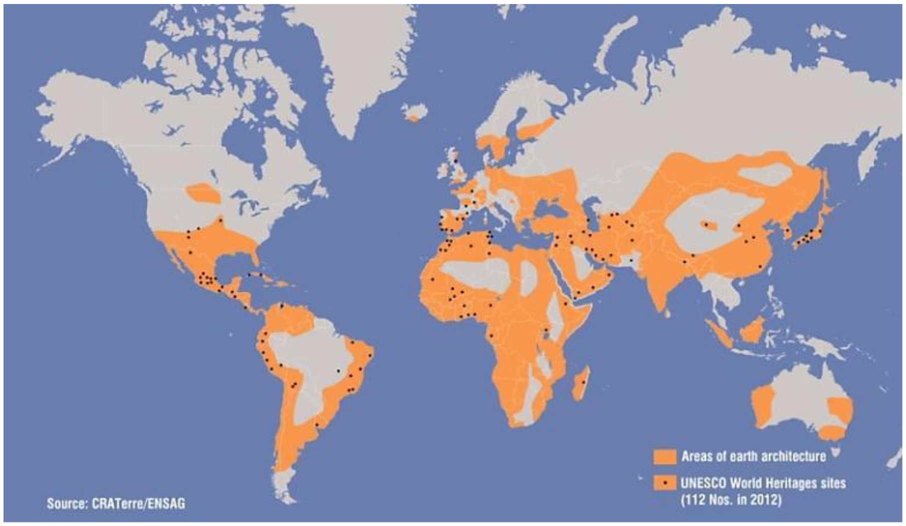

Figure. 1: Earth building distribution and using areas around the world. [7]

Figure. 2: Zakho (traditional earth building).

Zakho is unique in its architecture of its earth building. Houses building which almost four to five stories in height are made of mud using traditional cob techniques. Mud cob building and construction in the Zakho Valley has been an active regional industry for last centuries providing durable and attractive buildings (Fig.3). It has recently become affected by many public, economic and private changes.

Using local materials and “cob” technology earth building in Zakho valley has a great heritage of sustainable buildings. The tradition of mud “cob” architecture in the Zakho valley offers a unique source of cultural and technical knowledge (Fig.

4). Identify the characteristics of the soil and its appropriateness is very important for using it in building construction in order to improve their quality [8, 9, 3]. Before applying, material should be prepared, which usually consists of sieving, pulverizing and drying [5]. It is important to ensure that the materials used in construction meet all the specification in every respect. This means that all relevant properties must be checked properly before construction [10]. We can promote the use of earth as a building material by understanding the characteristics of soil [11].

This study is an attempt to summarize information on the basic characteristics of the selected soil. The study will support the use of modern earth techniques as a building material in Zakho and it will focus on soil properties for building materials and wall building knowledge. It is worth mentioning that this study is considered a first research in this field in the Zakho province.

Figure. 3: Durable and attractive buildings of mud cob building in the Zakho Valley.

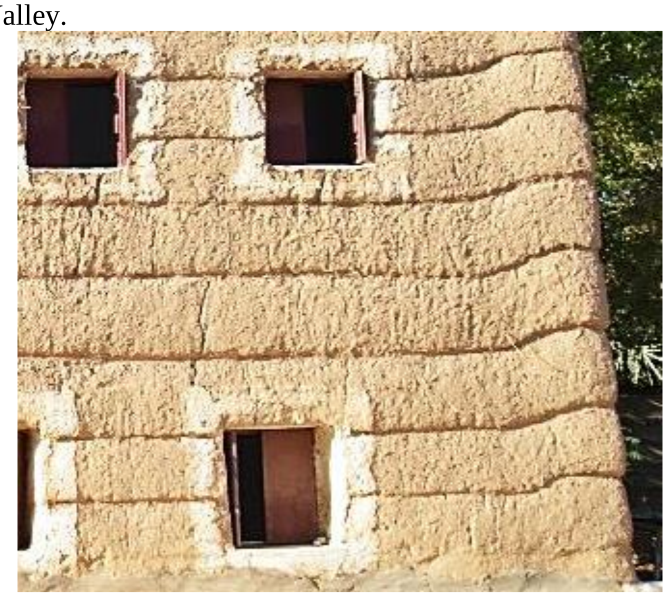

Figure. 4: The tradition of mud “cob” architecture in the Zakho valley

1.1 Problem statement

In spite of all earth material and buildings advantages, soil material is still unsuitable for use in many countries, mainly attributed to the disadvantages of this material and lack of information on its properties. Lack of building material properties was a problem to understand the earth building demands and the enhancing methods, which are only, refer to the local masons and their professionals. Many researches in this area focused on using the material for traffics, roads and construction foundations, mostly [3]. There is still poor understanding of the soil selections for scientific engineers and architecture demands. Soil is not receiving the required researches and attention as a material for earth block and wall construction [12].

However, traditional knowledge was mostly is no longer sufficient or last [13].

1.2 Research objectives

This study was conducted to gain a better knowledge and understanding of the characteristics of the local earth materials of Zakho city. Classifying the local material that used in earth building construction for further researches and developing building material.

2. Properties and Characteristics of soil for earth production

Previous studies had shown that the physical properties of soil must be checked before starting any important work [11]. It is commonly accepted that the soil to be used in earth building walls should have a high sand content with just enough clay in it to act like a binder. Too much clay can give cracking problems due to shrinkage effects [13]. Particle size distribution or texture of the soil is an important characteristic. Highly plastic clay, clean gravels, sand and organic soils are unsuitable and not recommended [14, 15, 16, 3].

Swell capacity and soil shrinkage are related to their clay content. 30% of clay is the basic formula with balance loam and small amount of aggregate [17]. Silt percentage should be less than one third. California's Uniform Building Code Specification recommends 55 to 75% sand, and 25 to 45% clay and silt [18] Table1 shows these percentages.

Table 1: An idea for good mixture for most blocks [18]

Specifications	Percentage	Specifications
Sand	65	Sand
Clay	20	Clay
Silt	15	Silt

Proposals were suggested for a range of 30% -70% balances between clay/silt and sand [19]. Researches summarize that the upper clay silt limit is 45% [20]. According to (Burroughs, 2001), the satisfactory of clay/silt is 36-45 percentage, while sand should be between 66 to 75%. Similarly, the minimum percentage of sand is between 50% -55% while the maximum is between 70% - 75%.

2.1 Soil types and classification

Clay deposits: made up of similar and several clay minerals. Clay deposits have different working characteristics because of its plasticity and its ability to bind non-plastic additives [21, 22]. In many soil classification systems, soils are divided into three main groups: coarse, fine and organic [23]. Mechanical properties of soil, such as strength and permeability are dependent on the soil stress and grains, unit weight and the water content [24, 25]. When using soil for construction and engineering purposes, the British soil classification is recommended [26]. The classification is based on the range of particle sizes. British Standard BS1377:1990 [27] classification for particle sizes encountered in soil range from boulders with a controlling dimension of over 200 mm down to clay particles less than 0.002 mm. Some clay contains particles less than 0.001 mm in size [24] Fig. 3.

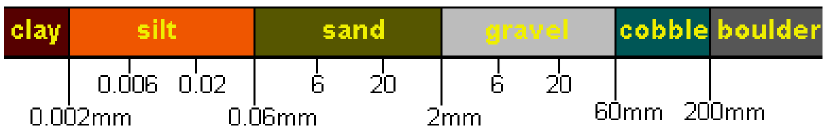

Figure. 5: The range of particle sizes in the soil

2.2. Characteristics of soils

Engineering behaviors are highly differences between clays and sands [24, 28]. The principal characteristics differences are particle size distribution, shape, and plasticity, while shape texture and Color are secondary characteristics [29, 30]. Chemical properties are depending on the chemical composition of the soil components and the quantity of magnesium, or calcium, carbonate oxides of iron, and sulphates. The pH level, soils do not usually stray very far away from the neutral point [31].

2.2.1 Physical index properties (basic characteristics of soils)

1- Porosity or voids ratio: Voids between the particles in the material itself can vary enormously depending on the particle size and distribution of the soil. Both the apparent bulk density and the specific bulk density of the sample are needed to calculate the porosity of a sample of soil [29, 32].

2- Specific bulk density: The specific bulk density of soil is calculated from the mass of the sample and the displaced volume of water similar to the apparent bulk density.

3- Specific gravity: Specific gravity (Gs) means the property of the mineral or rock material forming soil grains [24].

The range of specific gravities for soils is small, except for organic soils. Most soils (sand and clay) have a typical specific gravity of 2.65 [33]. The range of Gs for common soils is 2.64 to 2.72 [24].

4- Volume-weight properties

The volume-weight properties of a soil define its state and measure the amount of void space, amount of water and the weight of a unit volume of soil [24].

5- Shrinkage

In most clay-textures, the moisture content changes the soil volume depending on the type and amount of clay found in the soil. At the soil surface, shrinkage and swelling are seen as cracks and develop when the soil dries [16]. Shrinkage of soil is a very common problem and must be addressed carefully [34]. A measure of the soil shrink is determined by measuring a specimen in wet and dry conditions. The change in dimensional variation should be only around ±2 mm based on B.I.S code IS 1377, 1990 Part 2 [35]. Generally varies from near zero to 0.12 for soils [36]. Some other standards determined 3% Shrinkage as a maximum permissible linear shrinkage [20].

6- Dry density

Dry density is the degree of compaction of a soil, which is important to calculate loads on structural elements (measured in terms of dry density) referred to as the “Zero air voids” dry density or the saturation dry density [37].

Soil compaction

Compaction decreases permeability and reduces settlement of foundation.Compaction process effectiveness depends on several factors [23]. Soil dry density depends on the amount of moisture during compaction. There is one moisture content for each given soil called “optimum moisture content” that occurs in maximum dry density [26].

Optimum moisture content and bulk density

A standard compaction test was conducted following BS 1377:1990 part 4 [38] to determine the relation of dry density versus moisture content. Density is defined as the measure of how many particles of an element or material are squeezed into a given space.

2.2.2 Relationships between basic properties:

1- Property index (plasticity) Plasticity is the property of soil that describes deformation without elastic failure i.e. cracking or breaking [39& 40], which is indicated by the plasticity index [20].

2- Liquid limit (wL) – is the change of consistency from plastic to liquid.

3- Plastic limit (wP) – is the change of consistency from brittle/crumbly to plastic

Plasticity Index (IP or PI) is calculated by the formula

IP = liquid limit - plastic limit = wL - wP [24].

The Atterberg limits are utilized in specifications to control the properties, compaction, and behavior and to describe the transitions of soil material from semi-solid, to plastic, to fluid. Sandy soils and silts have low plasticity index values, while most clays have higher values.

Liquid limit for earth soils should be between 25% and 50% (30% - 35% preferred) and the plastic limit between 10% and 25% percentages of 12% - 22% are preferred [31].

7- Organic content

Sample of the cohesive soil was tested and a quantity of organic content was also recorded in following of BS 1377: 1990 part 3 [41].

3 Field and laboratory test work

3.1 Soil selection

Two locally soils were selected from Zakho valley. Both samples were from earth building construction sites. First conducted testing was the visual testing to choose the best and pure building soil. The first location was in Najran valley near the heritage and old clay buildings. Visual testing and pilot laboratory experiment showed that the second site soil (Zur Wadea,a) was mixed with organic materials. Thus, the first site (Zakho Valley) was recommended and trusted for the laboratory experiments to find its properties.

Figure. 6: Soil sight selection in the middle of Zakho valley

3.2 Laboratory Experiment

According to the literature review, the most important tests were selected and conducted to define soil sample properties for earth construction and buildings. Using the chosen soil, the sample was prepared and experiments were done in civil engineering laboratories of college of engineering at Zakho University. British standard tests were recommended and used. Testing was done in three phases:

i- Visual and simple tests to define the types of soil that seems suitable.

ii- ii- Sieve analysis to determine the particle sizes and percentage of clay in the soil.

iii- ii- Laboratory tests to determine the engineering properties of the cohesive soil.

1- Sieve analysis

Sieve tests were carried out. Wash sieving standard method: Per B.S. 1377:1990 [42] was used to determine the particle sizes of the samples. The used apparatus were included B.S. test sieves (10 mm, 5 mm, 2 mm, 1.18 mm, 0.63 mm, 0.30 mm, 0.15 mm, 0.063 mm) , mechanical sieve shaker (see Figure.5), sieve brush, trays or container, balance, oven and sodium hexametaphosphate.

Figure. 7: B.S. sieve set and mechanical sieve shaker

About 500 gm of air-dried soil was placed in a bucket and covered with tap water. Then, about 2 mg of sodium hexametaphosphate was added to it and the mixture was stirred thoroughly. After that, the soil was washed through a 63 µm B.S. test sieve and the fine material passing through it was allowed to run to waste. All the retained material was collected in a proper dish and put in an oven at 110°C for 24 hours to dry. Then, the dried material was taken out from the oven and let to cool. After cooling, the dried material was sieved through appropriate set of sieves, using a mechanical sieve shaker for about 10 minutes. The soil retained in each sieve was weighed. The cumulative percentages by masses of the samples passing through each of the sieves were calculated and results were also recorded.

2- Characteristics of the cohesive soil (soil properties)

(a) Optimum moisture content and bulk density: a standard compaction test was conducted following BS 1377:1990 part 4 [38] to determine the relation of dry density versus moisture content.

(b) Grain specific gravity (Gs): a standard method was used according to British standards (BS 1377: 1990 part 4) [43]. G_s = [mass of soil/ mass of water displaced by soil].

(c) Organic content: organic content quantity was also recorded following (BS 1377: 1990 part 3) [41].

(d) Linear shrinkage: a standard method (BS 1377: 1990 part 2) [35] was applied to determine the linear shrinkage of the soil. The linear shrinkage was calculated by the equation:

Percentage of linear shrinkage = [1- (length of oven dry specimen/initial length of specimen)] *100. The results were reported to the nearest whole number.

(e) Liquid limit and plasticity: to determine the liquid limit (LL) of the air-dried soil, the cone penetration method (BS 1377: 1990 part 2) [44] was used and the moisture content was taken. The natural moisture content, liquid limit and plastic limit were determined. Results were also recorded.

4 Results and Discussions

4.1 Result of sieving

The results of a wash-sieving test according to sieve analysis standard (BS 1377:1990) [42] is given in (Table 2) together with the grading analysis and grading curve in (Fig. 5).

Table 2: Determination of the particle size distribution of soil sample

B.S Test Sieve Size (mm)	Weight Retained (g)	Weight Passing (g) by mass	Percentage passing (% by mass)
5.0	13.5	493.5	97.3
2.0	55.5	438	86.4
1.18	41	397	78.3
0.60	36.5	360.5	71.1
0.30	68	292.5	57.7
0.15	40	252.5	49.8
0.063	67	185.5	36.6
Total	321.5	-----	37%

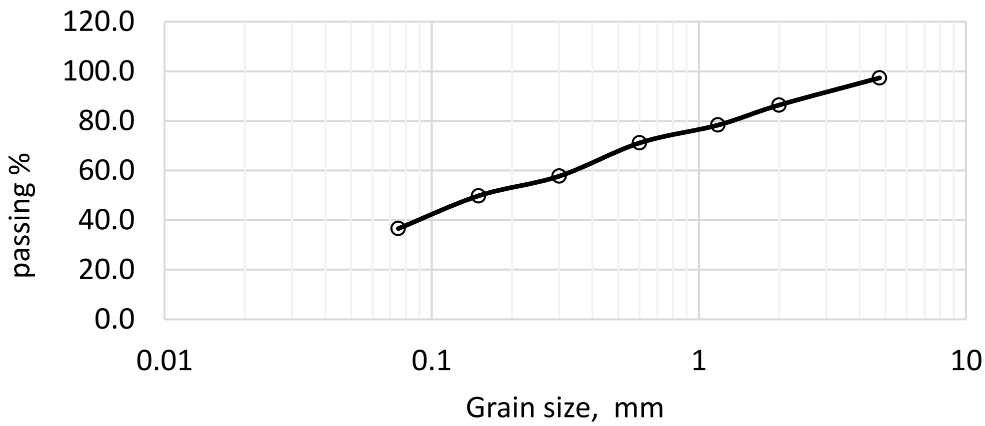

Figure. 8: Grading curve of the soil sample

Variety range of particle size for earth construction is recommended, because of the wide varieties of this material. Thus, the selected soil was in the recommended zones. Grading curve of the particle size clearly shows that this soil has about 36.6% of clay silt particles, and 60.7% of sand which is in the average of standards and has a balanced amount of particle sizes between coarse and fine particles. California's Uniform Building Code Specification, which is one of the few soil block standards, recommends 55 to 75% sand, and 25 to 45% clay and silt [18]. Results in the table and figure above satisfied this specification, which means the suitability of this soil for making blocks.

4.2 Shrinkage

Shrinkage results show a percentage of 1.9 % which is in the acceptable range stated in the literature review. These results are recording in Table 3.

Table 3: Shrinkage results

	R (mm)	L (mm)	Ms (gm)
Weight, length and radios for the wet sample	12.5	140	66.85
Weight, length and radios for the dry sample	11.79	137.35	52.58

4.3 Liquid and plastic limits determination

Table 4 and Figure 7 are presents the results of liquid limit (LL) tests. From the Figure 7, it is seen that the LL is about of 31%. The plastic limit (PL) was determined as 27.4%. Houben and Guillaud [45] reported that liquid limit for earth soils should be between 25% and 50% (30% - 35% preferred) and the plastic limit between 10% and 25% percentages of 12% - 22% are preferred. Danso [46] has concluded that the upper limits of liquid limit and plasticity index are 50% and 30%, respectively. In comparison with these criteria, the results of LL and PL of the tested soil are within the accepted range for the suitability of soils to earth block making.

Table 4: Liquid limit results

Penetration D (mm)	8.5	12.2	19.1	25.5
Can no.	5	16	13	3
Mass of wet soil+ can (gm)	42.723	41.786	43.097	42.978
Mass of dry soil+ can (gm)	40.586	39.627	40412	40.156
Mass of can	31.553	31.606	31.406	31.583
Mass of dry soil (gm)	9.033	8.021	9.006	8.573
Water content %	23.7%	26.9%	29.8%	32.9%

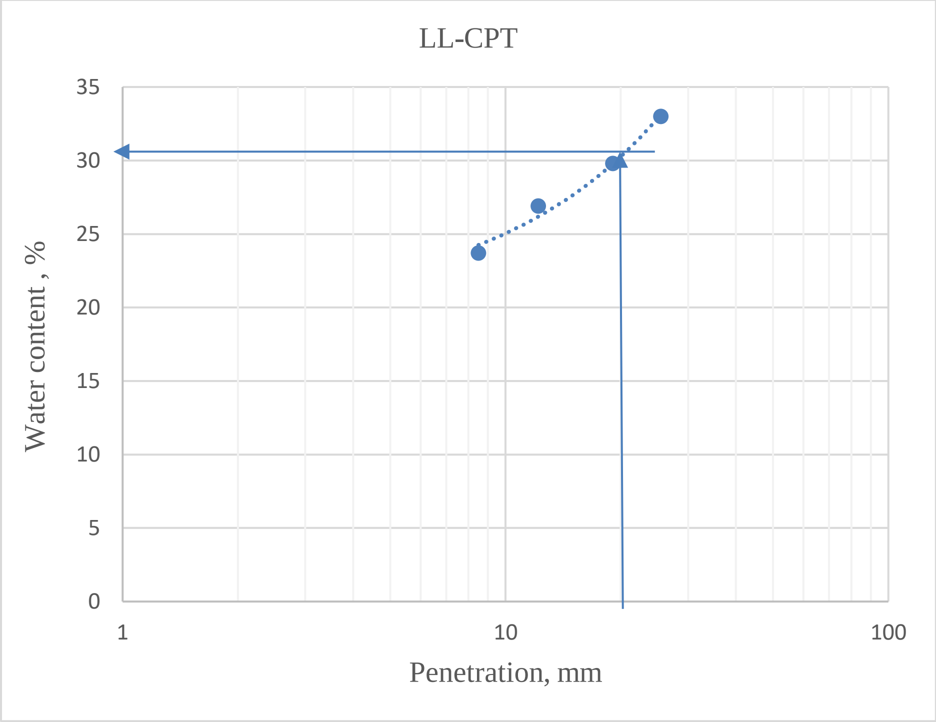

Figure. 9: Penetration versus water content for liquid limit determination.

4.4 Specific gravity

Specific gravity is an important property in which it is used to relate the weight of the soil to its volume and it is very beneficial in the phase shape relationship calculations. The results showed that the specific gravity of the soil sample is about 2.74. Danso [46] adopted 2 and 2.8 as lower and upper limits for the specific gravity of the soil suitability for earth construction. Based on this, the tested soil laid within the acceptable and preferred range of soils suitable for earth block making.

4.5 Compaction test results

Compaction process is simply expelling the air from the voids of the soil. Optimum moisture content shows low voids of the tested soil and maximum dry density. About of 10% of moister content was recorded as an optimum. This result clearly showed the ability of this material for earth building and its construction. These results are presented in Figure 8. From the figure, it can be seen that the optimum water content and the maximum dry unit weight of the tested soil are about of 10 % and 19.56 kN/m3, respectively. When the soil is compacted at the optimum water content, the maximum dry density is achieved and hence it has a direct improvement in bearing and durability. These features are very important in earth blocks making. Although there are no known criteria for acceptable optimum moisture content and maximum dry density, some researchers tried to put a range for the desired values. Houben and Guillaud [45] indicated a range of values for the optimum moisture content of 3.5% to 14% and maximum dry density between 1750 kg/m3 and 2000 kg/m3. Considering the results obtained, we can conclude that the optimum water content and the maximum dry density are within the preferred ranges.

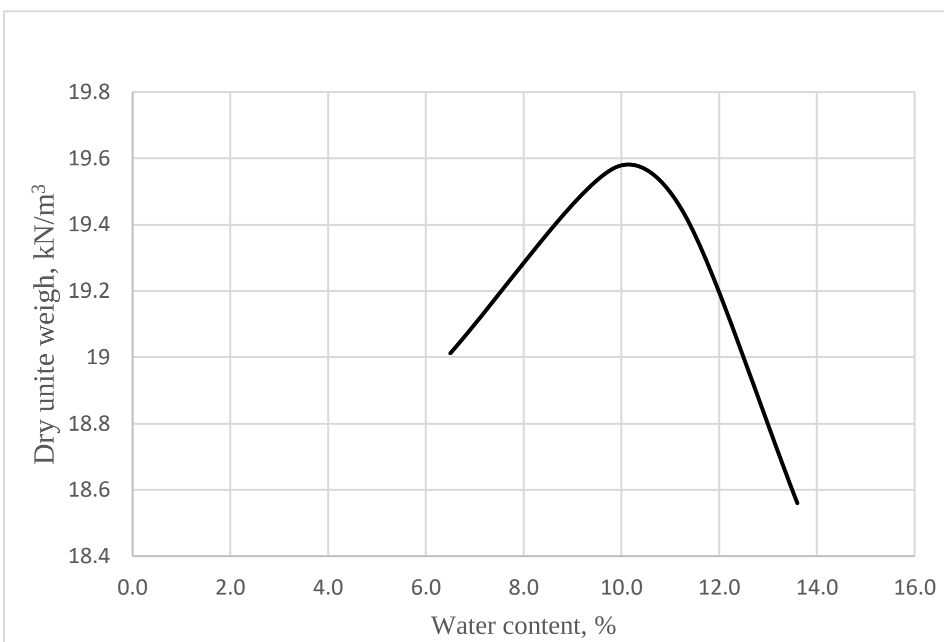

Figure.10: Relationship between water content and dry unit weight of soil.

5 Results summary

For soil to be used as a building material in earth blocks construction, some geotechnical properties should be assessed and analyzed. These properties are mainly grain size distribution, plasticity indexes, specific gravity, optimum moisture content and maximum dry density. The summary of the results of these engineering properties of the selected and tested soil sample are reported in Table 5.

Table 5: Soil Properties

Properties	pH	Organic content	Specific gravity	Linear shrinkage	Optimum Moisture	Dry density (kN/m3)	Liquid Limit (L.L)	Plastic Limit (P.L)	Plastic Index (P.I)
Results	4.9	5.21%	2.74	8.21%	10%	19.57	31%	27.4%	3.6%

Based on the results, it is concluded that the determined values of the geotechnical properties of the soil sample satisfied criteria reported in the literature and discussed in the result discussion part before. The ratio of organic content and the pH value are low. It is worth mentioning that mechanical and engineering properties of soils change from one site to another.

6 Conclusion

This study compiled soil samples and compare it with soil suitability criteria for recommending suitable soil for earth construction purposes and techniques (adobe, rammed earth and compressed earth blocks) Local soil which was taken from the city of Najran revealed that it can be used for building construction as walling units. Results showed suitable properties for earth construction and clay content was in the proper average.

REFERENCES

[1] M. A. A. Al-Jadeed, “Mud Architecture in Arab & Western Countries,” *Journal of Al-Madinah Al-Munawwarah Research & Studies Center*, 8(2), 105-138, 2004.

[2] J. Middendorf, “Properties and Methodology of Earth Structures,” *Harvard Graduate School of Design*, (E. a. E. Addington), 2001.

[3] A. Fabbri, J. Morel, and D. Gallipoli, ”Assessing the performance of earth building materials: a review of recent developments”, *RILEM Technical Letters*, 30, pp. 46-58, 2018

[4] J. C. Morel, A. Mesbah, M. Oggero, P. Walker, ” Building houses with local materials: means to drastically reduce the environmental impact of construction,” *Build Environ* 36 (10): 1119–1126, 2011, 2016.

[5] D. Easton, T. Easton,”Modern rammed earth construction techniques,” *Modern Earth Buildings*, p 364-384, 2012.

[6] J. Vyncke, L. Kupers and N. Denies,” Earth as Building Material – an overview of RILEM activities and recent Innovations in Geotechnics” *MATEC Web of Conferences* 149, 02001, 2018.

[7] A. Earth Institute [Internet]. Earth-auroville.com. [cited 6 March 2016]. Available from: *http://www.earth*

[8] R. Stulz, and K. Mukerji,"Appropriate Building Materials. A catalogue of Potential Solutions," (Second, revised ed," *Gallen Swiss Canter for Appropriate Technology (SKAT Switzerland),* 1988.

[9] A. G. Kerali,"Durability of Compressed and Cement-Stabilised Building Blocks. *Unpublished Doctor of Philosophy in Engineering, University of Warwick, Warwick,* 2001

[10] R. Tuffin,"READING – PRESSURE VESSELS – CONSTRUCTION AND TESTING, 2007. *Retrieved 18/3/2008. from www.worksafe.wa.gov.au/institute.*

[11] E. A. Adam, and A. Agib, "Compressed Stabilised Earth Block Manufacture in Sudan," Paris: *United Nations Educational, Scientific and Cultural Organization,* 2001.

[12] I. Maria, D. Teresa and F. Paulina," Unstabilized Rammed Earth: Characterization of Material Collected from Old Constructions in South Portugal and Comparison to Normative Requirements," B. Milt, "Compressed earth block (CEB) construction: a viable building alternative for Olancho, Honduras," *Department of Construction Managemen .In partial fulfillment of the requirements For the Degree of Master of Science Colorado State University Fort Collins,* Colorado, 2014.

[13] L. A. Wolfskill," Handbook for building homes of earth," (Vol. 21). Agricultural and Mechanical College of Texas: *Transportation Institute, Bulletin,* 11963.

[14] UN., " Earth Construction Technology", United Nations Centre For Human Settlements," Nairobi,1992

[15] V. S. Burroughs, " Quantitative criteria for the selection and stabilization of soils for rammed earth wall construction, "*Unpublished Built Environment, University of New South Wales Sydney,* 2001.

[16] B. Christensen, " Book earth guidelines, " http://greenbuilder.com/sourcebook/EarthGuidlines.html

[17] B. Sidibe, " Understanding Adobe. TECHNICAL PAPER # 24, 1985 Retrieved 6/4, 2006, from *http://sleekfreak.ath.cx:81/3wdev/VITAHTML/SUBLEV/EN1/ADOBE.HTM*

[18] Eaton, " Ruth Mud: an examination of earth architecture," *Architectural Review,* Vol.1016, 1981

[19] V. Maniatidis, and P. Walker, " A Review of Rammed Earth Construction for DTi Partners in Innovation Project 'Developing Rammed Earth for UK Housing," Bath: *Natural Building Technology Group (Department of Architecture & Civil Engineering) University of Bath,* 2003.

[20] R. Velckenborg, "NMR on technological porous materials," *Eindhoven University of Technology,* Eindhoven, 2001.

[21] N. Ural, ”The Importance of Clay in Geotechnical Engineering, Current Topics in the Utilization of Clay in Industrial and Medical Applications,” *Mansoor Zoveidavianpoor, IntechOpen*, pp 83-102, 2018, DOI: 10.5772/intechopen.75817. Available from: https://www.intechopen.com.

[22] R. Whitilow, ” Basic Soil Mechanics, “(Third ed.). *Malaysia: Longman,* 1995.

[23] L. Davison, and S. Springman, ” Soil description and classification,” Retrieved 23/6, 2007, from http://environment.uwe.ac.uk/geocal/SoilMech/classification/soilclas.htm

[24] S. Roy, and S.K. Bhalla, ”Role of Geotechnical Properties of Soil on Civil Engineering Structures,” *Resources and Environment, Scientific & Academic Publishing*, July 2017. URL: http://article.sapub.org/10.5923.j.re.20170704.03.html. Accessed on 16 April 2019.

[25] F.H. Chen, ”Soil Engineering, Testing, Design, and Remediation,” *Florida: CRC Press LLC*, 1999.

[26] B.S., ”British standard Methods of test for Soils for civil engineering,” *England: British Standard Institution,*1990

[27] H. Mekkiyah and A. Al-Khazragie, ”Behavior of clay soil mixed with fine sand during consolidation,” *Applied Research Journal*. 1: 437-443, 2105

[28] D. E. Montgomery, ”Design and Realisation of a Test Rig to Research the Production of Full Size Dynamically Compacted Soil-Cement Blocks,” *University of Warwick, UK*,1997

[29] L. Cely-Illera, C.V Cely-Illera, and K. Anteliz-Contreras, ”Evaluation of the technological characteristics of clay when adding building materials to manufacture structural products without implementing a sintering process,” *Ciencia e Ingeniería Neogranadina*, volume 26-2, pp. 5-20, 2016.

[30] H. Houben and H. Ggillaud, ”Earth Construction-A comprehensive guide,” London: *CRATerre-EAG, Intermediate technology publications*, 1994.

[31] P. R. Chaudhari and V. D. Ahire ”Soil bulk density as related to soil texture, organic matter content and available total nutrients of Coimbatore Soil. *International Journal of Scientific and Research Publications,* 3(2): 1–8, 2013.

[32] W.L Schroeder, S.E. Dickenson, and D.C Warrington, ”Soils in Construction.,” In (5th ed.). *New Jersey Pearson Prentice Hall*, 2004

[33] A. Guettala, A. Abibsi, and H. Houari, ”Durability study of stabilized earth concrete under both laboratory and climatic conditions exposure,” *Construction and Building Materials* 20, 119-127, 2006.

[34] B.S. ”Determination of shrinkage characteristics, British standard Methods of test for Soils for civil engineering purposes,” *England: British Standard Institution,* (Vol. BSI 1377:1990 Part 2).

[35] M. J Singer, and D. N Munns, ”Soils an introduction,” (4 ed.). *New Jersey Macmillan Publishing Company,* 1999.

[36] R.F Craig, ”Soil Mechanics,”(Fifth ed.). *London: Chapman & Hall*, 1993

[37] B.S. ”Determination of the dry density/moisture content relationship and determination of the optimum moisture content,” *British standard Methods of test for Soils for civil engineering purposes* (Vol. BSI 1377:1990 Part 4). England: British Standard Institution.

[38] N. C Brady, ”The nature and properties of soils,” 8th Edition, *MacMillan Publishing Co. Inc., New York*, 1974

[39] F. A. Andrade, H.A Al-Qureshi and D. Hotza, ”Measuring the plasticity of clays: A review, Appl,” *Clay Sci*. 51 (2011) 1–7, 2011.

[40] B.S. ”Determination of the organic matter content,” *British standard Methods of test for Soils for civil engineering purposes,* Vol. BSI 1377:1990 Part 3.

[41] B.S. ”Determination of particle size distribution, wet method,” *British standard Methods of test for Soils for civil engineering purposes,* Vol. BSI 1377:1990 Part 2.

[42] B.S. ”Determination of specific gravity,” *British standard Methods of test for Soils for civil engineering purposes,* Vol. BSI 1377:1990 Part 4.

[43] B.S. ”Determination of the plastic limit and plasticity index,” *British standard Methods of test for Soils for civil engineering purposes*, Vol. BSI 1377:1990 Part 2.

[44] H. Houben, and H. Guillaud, ”Earth construction: a comprehensive guide,” *London: Intermediate Technology publications,* (1st edition 1994), 2006.

[45] H. Danso, (2018).”Suitability of Soil for Earth Construction as Building Material,” *Advancements in Civil Engineering & Technology*, volume.2 issue.3.pp 199-211, 2018. Alhayani B., H. Ilhan.(2020). “Image transmission over decode and forward based cooperative wireless multimedia sensor networks for Rayleigh fading channels in medical internet of things (MIoT) for remote health-care and health communication monitoring,” Journal of Medical Imaging And Health Informatics, vol. 10, pp. 160-168.

[46] Alhayani B.,H.Ilhan. (2020). Efficient cooperative imge transmission in one-Way mult-hop sensor network,” International Journal of Electrical Engineering Education, vol.57, no.2, pp.321-339

[47] Alhayani, B. and Abdallah, A.A. (2020), "Manufacturing intelligent Corvus corone module for a secured two way image transmission under WSN", Engineering Computations, Vol. 37 No. 9, pp. 1-17.

[48] ALhayani, H. Ilhan, (2017). **“Hyper spectral image classification using dimensionality reduction techniques”,** International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering**,,** vol.5, pp.71-74.

[49] Alhayani, Milind Rane. (2014). ”face recognition system by image processing” International journal of electronics and communication engineering & technology (IJCIET),vol.5, no.5, pp. 80–90.

[50] B. Al-Hayani, H. Ilhan. (2020)“Visual Sensor Intelligent Module Based Image Transmission in Industrial Manufacturing for Monitoring and Manipulation problems,” Journal of Intelligent Manufacturing, vol.4,pp.1-