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KAOLINITE CHEMICAL ELEMENT AND MORPHOLOGY PROPERTIES IN GEOMORPHOLOGY

ABSTRACT:

The geotechnical problems could be investigated with different methods, in this research work authors made an investigation on kaolinite modified under the thermal for 6 hours from 100ºC to 500ºC in increment of 100ºC for studying morphology, chemical composites and mechanical properties behavior of soil using SEM, XRF and triaxial tests. The result revealed that the thermal not changing kaolinite unit weight and cohesion up to application of 500ºC it could be expected of well resisting of this material under fire and also the thermal modified kaolinite angle of friction and it is resulted in the improvement of safe bearing capacity. And this is observed that the improvement of kaolinite mechanical characteristics under heat is not due to changing chemical composite and morphology this is may be due to modification of structural atomic of kaolinite minerals. It could be suggested that thermal could modified construction material and using that without shaping in the factory, and could be used as an unformed material and use as per requirements in the site for solving geotechnical problem like settlement, deformation, stability and failure of subsoil and structures.

KEYWORDS:

Stability; Bearing capacity; SEM; Cohesion; Angle of Friction

INTRODUCTION

The kaolinite is one of the important material, this could be modified trough the investigation to finding appropriate construction material for reduction of geotechnical problem based on economically.

There is investigation on Thermal conductivity values, in the temperature range 300 - 1200 K, have been measured in air and at atmospheric pressure for a Kenyan kaolinite refractory with 0% - 50% grog proportions. The experimental thermal conductivity values were then compared with those calculated using theoretical models. On the contrary, the conductivity values for the sample containing ≥ 40% decreased with increase in temperature in a manner consistent with the Eucken law [1]. There is research on physico-mechanical properties of fired clay bricks manufactured with different percentages of CBs are reported. The results show that the density of fired bricks was reduced by up to 30 %, depending on the percentage of CBs incorporated into the raw materials. Similarly, the compressive strength of bricks tested decreased according to the percentage of CBs included in the mix. The thermal conductivity performance of bricks was improved by 51 and 58 % for 5 and 10 % CBs content respectively [2]. It has been reported on the deep clays exhibit pronounced strain anisotropy both during mechanical loading as well as during heating and cooling at constant stress in drained isotropic conditions. During mechanical loading vertical strain is larger than the horizontal one. During heating the vertical strain is larger than the horizontal one within the elastic range; the opposite is observed in the elasto-plastic range. The above described response can be interpreted adopting a consistent rotational, kinematic hardening thermo-elasto-plastic constitutive law [3]. In a scientific work it has been presented a new thermo-plastic mechanism for isotropic thermo-mechanical paths including thermal hardening. It is based on considerations of the thermal effect on void ratio. After a discussion of the experimental evidence, the formulation of the thermo-plastic yield mechanism is introduced. Typical features are analyzed and the responses of the model discussed. The proposed model is validated on the basis of experimental results on two different clays [4]. There is an investigation on thermal effects on the mechanical behavior of saturated clay. The study was performed on CM clay (kaolinite) using a temperature-controlled triaxial apparatus. Applied temperatures were between 22 and 90ºC, The obtained results provide observations concerning a wide scope of the thermo-mechanical behavior of clays [5]. Research interest in the thermo-mechanical behavior of soils is growing as a result of an increasing number of geo-mechanical problems involving thermal effects. These *problems with non-isothermal situations are mainly encountered in the field of environmental geomechanics [6]. It has been reported the differences between kaolinite and smectite structures are notable, mainly as a result of the degree of weathering in the different compounds. Nevertheless, the kaolinite structure possesses great advantages in many processes due to its high chemical stability and low expansion coefficient. As a consequence of adsorption, the kaolinite structure and the soil solution pH will change. To analyze the adsorption behavior of kaolinite, Pb, Zn and Cd were studied at three different concentrations (1, 2 and 3 mmol/l) and over different periods of exposure (0.1, 1, 2, 4, 8, 12 and 24 h). The kaolinite retained up to 10.0 Amol/g of Pb, 8.40 Amol/g of Zn and 6.00 Amol/g of Cd when it was mixed with the 3 mmol/l concentrations of heavy metals. In each case, the adsorption eventually reduced the solution pH from 4.6 to 3.7. The changes in pH over time indicated both the release and retention of hydrogen ions by the mineral, probably involving the hydroxyl edge sites and exposed hydroxyl planes. The size of the atomic radii are 1.81, 1.71 and 1.53 A° for Pb, Cd and Zn, respectively, compared to the 0.79 A° for H. This difference, along with the differences in hydrated radii, will affect the structure of the clay causing stress in the molecule. Changes in the mechanical and chemical properties of the clay are discussed as the interactions of the heavy metal cations with the kaolinite could affect the structure of the kaolinite and influence properties such as swelling capacity, compaction capability and the double-layer behavior. The kaolinite in this study contained some illite which may have increased the pH 7 cation exchange capacities to 17.8 mEq/100 g. using the adsorption data, the reactions at the clay water inter phase and the probable effects on the physical properties and structure of kaolinite are discussed. [7]. It has presented that the thermal behavior of a formamide-intercalated mechano-chemically activated (dryground) kaolinite was investigated by thermo-gravimetry-mass spectrometry (TG-MS) and diffuse reflectance Fourier transform infrared spectroscopy (DRIFT). After the removal of adsorbed and intercalated formamide, a third type of bonded reagent was identified in the 230 - 350°C temperature range decomposing in situ to CO and NH_3. The presence of formamide decomposition products as well as CO_2 and various carbonates identified by DRIFT spectroscopy indicates the formation of super-active centers as a result of mechano-chemical activation and heat treatment (thermal deintercalation). The structural variance of surface species decreases with the increase of grinding time. The ungrounded mineral contains a low amount of weakly acidic and basic centers. After 3 hours of grinding, the number of acidic centers increases significantly, while on further grinding the super-active centers show increased basicity. With the increase of grinding time and treatment temperature the amount of bicarbonate- and bidentate-type structures decreases in favor of the carboxylate- and monodentate [8]. It has find in a scientific research work that Contact freezing of single supercooled water droplets colliding with kaolinite dust particles has been investigated. The experiments were performed with droplets levitated in an electrodynamic balance at temperatures from 240 to 268 K. Under relatively dry conditions (when no water vapor was added) freezing was observed to occur below 249 K, while a freezing threshold of 267K was observed when water vapor was added to the air in the chamber. The effect of relative humidity is attributed to an influence on the contact freezing process for the kaolinite-water droplet system, and it is not related to the lifetime of the droplets in the electrodynamic balance. Freezing probabilities per collision were derived assuming that collisions at the lowest temperature employed had a probability of unity. Mechanisms for contact freezing are briefly discussed [9]. It is well established from the literature, experimental study and theory, about the effect of the heat on kaolinite characteristics and a number of theoretical and computational studies have been performed by various researchers to determine the clay behavior when submitted to the thermal it was understood that the clay behavior is changed due to application of thermal based on huge number of experimental and theoretical investigation executed but kaolinite mechanical behavior under the thermal for 6 hours from 100 ºC to 500 ºC in increment of 100ºC based on chemical element analysis, morphology in connection with triaxial experiments never has been documented. The purpose of the entire research exercise would be to (i) identification of bentonite chemical element, morphology and mechanical properties under thermal (ii) formulate some useful guidelines in using bentonite in the construction industry.*

METHODOLOGY AND EXPERIMENTS

Soil testing is an integral part of analysis and design in Soil Engineering. A proper evaluation of soil samples and determination of relevant soil properties simulating field-loading conditions are essential components of the practice of foundation engineering [10]. Researches in unsaturated soil mechanics considerably developed in the past decades, through the simultaneous development of experimental investigations and theoretical analyses [11]. To improvement of construction material a series experimental on soil submitted to thermal for 6 hours from 100ºC to 500 ºC in increment of 100 ºC executed. The main objective of the experiments was to analyze and development of ideal construction material in the laboratory condition. The evaluation of both for the macro and micro of kaolinite characteristics have been taken systematically trough of laboratory testing. In the laboratory triaxial and SEM tests were conducted. The affect of thermal on the kaolinite mechanical properties and morphology have been analyzed.

The triaxial test is a method for determination of shear strength of all types of soils under different drainage condition, in this method cylindrical *specimen submitted to the stress from all direction, this is subjected to confined pressure from the sides and also from the top gradually axial force applied up to shear failure of specimen. The axial force is the major stress and confides pressure is the minor stress and there is no shear stress form the side. The total axial stress at the time of shearing is sum of major and minor stresses. Due to increasing axial stress the shear stress developed based on compressive stress.*

The electron microscope is a scientific instrument for shape and size identification of the very fine scale objet that is a good representation and resolution of the three-dimensional particle it has more capability compare to light microscopes, the scanning electron microscopy (SEM) studies helps to understand the micro to macro surface features of the soil samples. The morphology of six soils sample was studied using SEM. The SEM studies of the six soil samples of the investigations were carried out using instrument; JSM-840A, JEOL-Japan. The SEM has been done to assessment of correlation between shape and size of soil particle with its mechanical properties.

The Terzaghi method has been used to calculation of soil foundation safe bearing capacity assumed depth of 1.5 m and widths of (2.5m) × (2.5 m). For all models, safe bearing capacity considered to assess soil foundation improvement thorough the interpreting of the suggested results. Formulas for calculation of safe bearing capacity are the following:

$$q_f = 1.3C\, N_c + \gamma D N_q + 0.4\, \gamma B N_\gamma \quad (1)$$

$$q_{nf} = q_f - \gamma D \quad (2)$$

$$q_s = (q_{nf} / F) + \gamma D \quad (3)$$

Also N_q, N_c and N_γ are the general bearing capacity factors and depend upon depth of footing, shape of footing and Φ, have been used from suggestion by the Terzaghi calculation method [12].

RESULTS AND DISCUSSION

When the thermal is applied on the kaolinite the weight of soil not changing that is reason unit weight almost is very close together. The table 1 indicated that increasing thermal not effected on improvement soil cohesion and could expect in same on permeability. The soil internal angle of friction is also increased. There is no linear correlation between increasing thermal and angle of friction but this is positive correlation, observation of this phenomenon helps for prediction kaolinite behavior in this temperature range without conducting soil mechanic experimental for modification of its characteristics based on thermal application. In the room temperature kaolinite has 1360.63 KN/m^2 safe bearing capacity, when submitted to the thermal for 500°C improved up to 4356.27KN/m^2.

Due to maintaining constant level of kaolinite cohesion at different level of temperature could be understood that the chemical composite is not changed and only structural atomic changed and it is reason of kaolinite mechanical behavior when this is submitted to the thermal.

Table 1 the Kaolinit mechanical properties

Model No	Temperature °C	γ (KN/m^3)	C (KN/m^2)	Φ [-]	SBC (KN/m^2)
1	RT	13.4	80	0	1360.63
2	100	13.1	80	7	1967.68
3	200	13.5	80	10	2312.03
4	300	13.3	80	15	3130.27
5	400	13.3	80	13	2801.60
6	500	13.1	80	20	4356.27

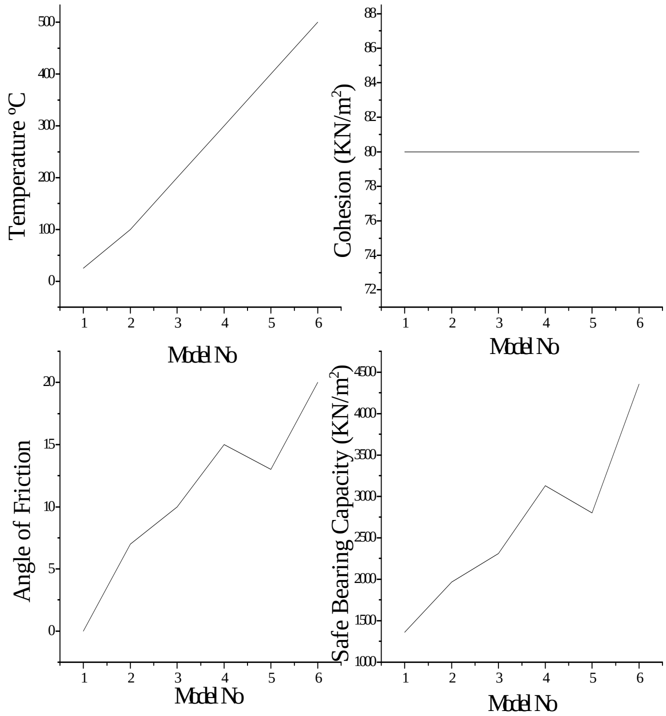

Figure 1. The Kaolinite mechanical properties

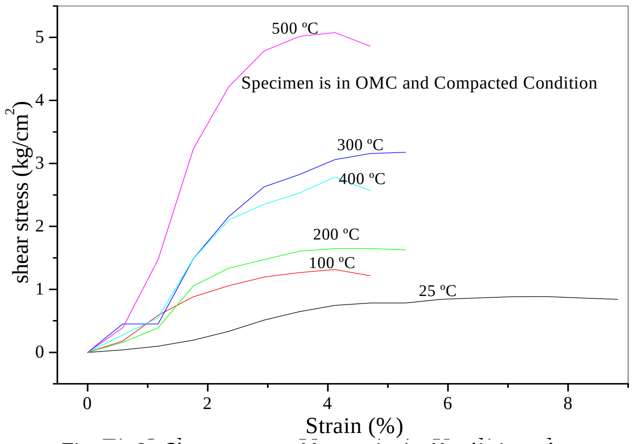

Figure 2. Shear stress Vs strain in Kaolinite clay

The fig 2 indicated that stress-strain relationship of Kaolinite at different level of temperature from triaxial test. When the thermal is increased the stress-strain relationship increased but not linear and always increasing of thermal not resulted of improvement of soil bearing capacity in this regard could bring example when soil is submitted to the 400°C. The SEM photographs have clearly revealed the surface morphology, shape and size of the minerals, which mechanically extracted from soils. In the Fig 3-8 indicated that the modification of soil morphology under all conditions are closely similar and there is not any significant change observed and also this kind of *result is observed about soil chemical composite from the XRF experiment (table 2) it could be expected that the soil structural atomic is main reason in modification of soil mechanical properties.*

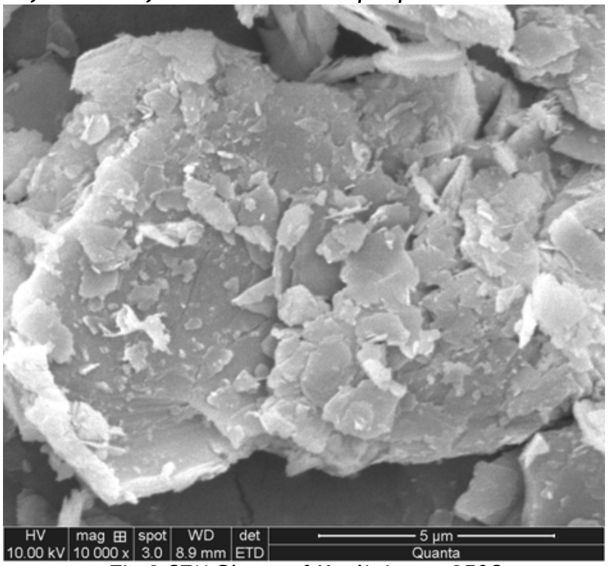

Fig 3 SEM Photo of Kaolinite at 25°C

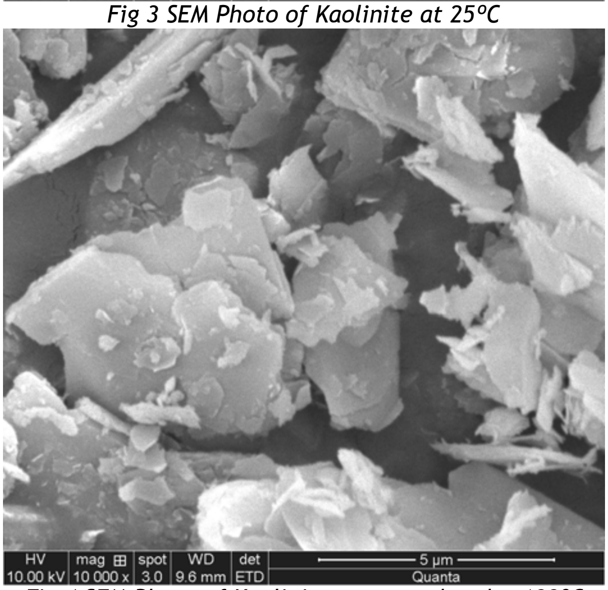

Fig 4 SEM Photo of Kaolinite processed under 100°C for six hours

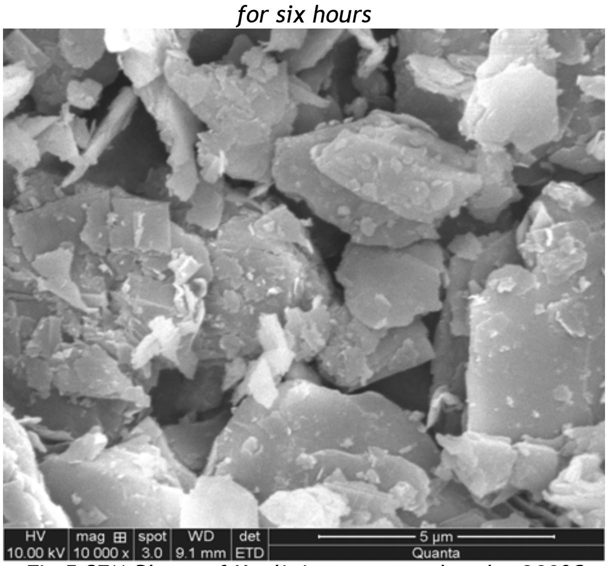

Fig 5 SEM Photo of Kaolinite processed under 200°C for six hours

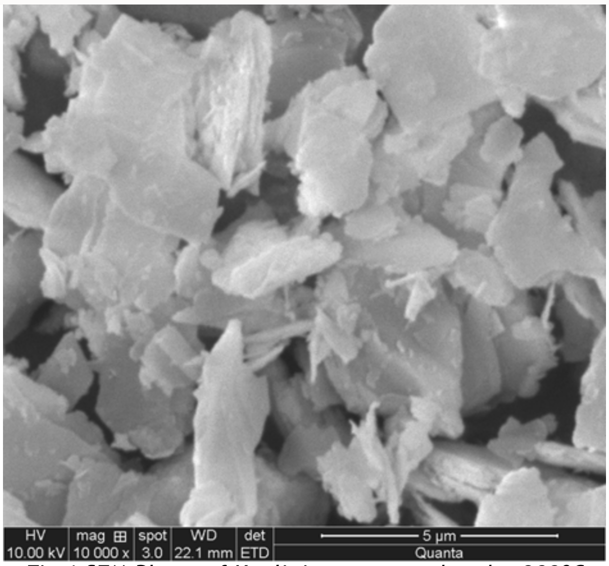

Fig 6 SEM Photo of Kaolinite processed under 300°C for six hours

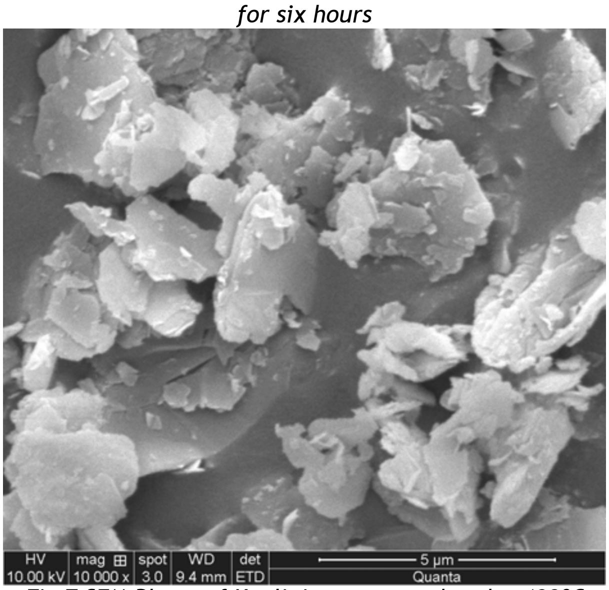

Fig 7 SEM Photo of Kaolinite processed under 400°C for six hours

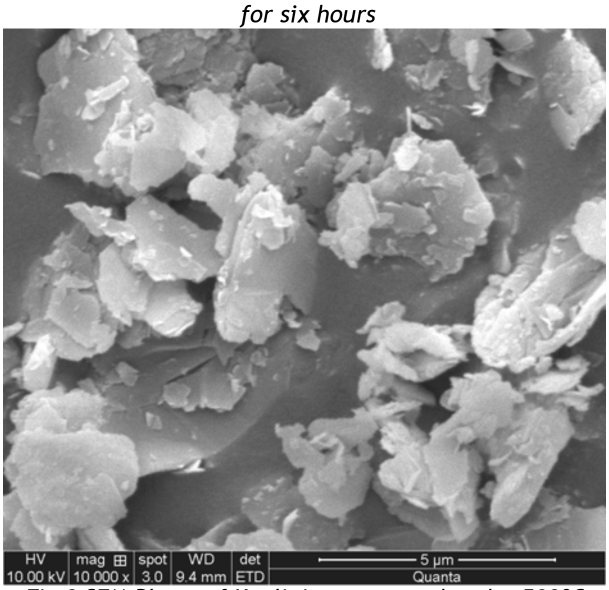

Fig 8 SEM Photo of Kaolinite processed under 500°C for six hours

The creation of thermal in some part of structure after construction due to positive affect on the subsoil and *improvement of some part also could causes of differential settlement and could be leads to structure instability.*

Table 2 Chemical element in the Kaolinite at different level of temperature

Heat °C		O	Al	Si	K	Fe
25	Wt %	48.94	13.58	30.20	6.07	1.21
	At %	63.54	10.45	22.33	3.23	0.45
100	Wt %	47.58	13.39	30.40	6.92	1.71
	At %	62.48	10.43	22.74	3.72	0.64
200	Wt %	49.49	13.94	29.19	5.92	1.47
	At %	64.09	10.70	21.53	3.14	0.54
300	Wt %	38.38	14.24	37.48	6.85	3.06
	At %	53.42	11.75	29.71	3.90	1.22
400	Wt %	42.06	13.19	36.21	5.95	2.58
	At %	57.08	10.62	28.00	3.31	1.00
500	Wt %	45.29	13.66	32.71	6.34	2
	At %	60.12	10.79	24.86	3.46	0.77

CONCLUSION

- *The thermal not changing kaolinte unit weight and cohesion up to application of 500 °C it could be expected of well resisting of this material under fire*
- *The thermal modified kaolinte angle of friction and it is resulted in the improvement of safe bearing capacity*
- *Improvement of kaolinte mechanical characteristics under heat is not due to changing chemical composite and morphology this is may be due to modification of structural atomic of kaolinte minerals*
- *From this investigation understood that the weak soil foundation could be modified using heat technique in suit for improving of soil foundation*

NOMENCLATURE

Φ (Degree)	=Angle of Friction
C (KN/m^2)	=Cohesive of Soil
OMC (%)	=Optimum Moisture Content
SBC (KN/m^2)	=Safe Bearing Capacity
γ (KN/m^3)	=Unit Weight
q_f (KN/m^2)	=Ultimate Bearing Capacity
q_{nf}(KN/m^2)	=Net Ultimate Bearing Capacity
q_s(KN/m^2)	= Safe Bearing capacity
N_c	= General Bearing Capacity Factor
N_q	= General Bearing Capacity Factor
N_γ	= General Bearing Capacity Factor
B (Meter)	= Width of the Foundation
D (Meter)	= Depth of Foundation
F	=Factor of Safety = (3)
SEM	=Scanning Electron Microscopy

REFERENCES

[1.] Kimani J. N. and Aduda B.O (2004),Temperature Dependence of the Thermal Conductivity of A Grog Modified Kenyan Kaolinite Refractory, African Journal of Science and Technology (AJST), Science and Engineering Series Vol. 5, 1, pp. 6 - 14

[2.] Aeslina Abdul Kadir et al (2009), Density, Strength, Thermal Conductivity and Leachate Characteristics of Light-Weight Fired Clay Bricks Incorporating Cigarette Butts, World Academy of Science, Engineering and Technology, http://www.waset.org/journals/waset/v53/v53-170.pdf

[3.] T. Hueckel and R. Pellegrini (1996), A note on thermo mechanical anisotropy of clays, Engineering Geology, Volume 41, Issues 1-4, Pages 171-180

[4.] L. Laloui, C. Cekerevac (2003),Thermo-plasticity of clays: An isotropic yield mechanism, Computers and Geotechnics 30, 649–660

[5.] Cane Cekerevac and Lyesse Laloui (2004), Experimental study of thermal effects on the echanicalbehaviour of a clay, Int. J. Numer. Anal. Meth. Geomech; 28:209–228 (DOI: 10.1002/nag.332)

[6.] Vulliet L, Laloui L, Harding R. (2002), Environmental geomechanics: an introduction. In Environmental Geomechanics, Vulliet L, Laloui L, Schrefler B (eds). EPFL-Press: Lausanne, 3–12.

[7.] Jorge C. Miranda.Trevino1, Cynthia A. Coles (2003),Kaolinite properties, structure and influence of metal retention on pH, Applied Clay Science 23, 133– 139

[8.] Frost, Ray and Horvath, Erzsebet and Kristof, Janos and Jakab, Emma and Mako, Eva and Vagvoelgyi, Veronika (2005) Identification of superactive centers in thermally treated formamide-intercalated kaolinite, Colloid and Interface Science, 289(1):132-138.

[9.] E. A. Svensson, et al (2009), Freezing of water droplets colliding with kaolinite particles, Atmos. Chem. Phys., 9, 4295–4300

[10.] Shamsher Parkash and P. K. Jain (2002), Engineering Soil Testing, Published by Nem Chand & Bros, Civil Lines, Roorkee

[11.] Pierre Delage(2002),Experimental unsaturated soil mechanics, Proc. 3rd Int. Conf. on Unsaturated Soils, UNSAT, (3) 973-996, Juca JFT, De Campos TMP, Marino FAM, Recife, Brazil, Balkema

[12.] B. C. Punmia, Soil Mechanics and Foundations, Madras, 1988

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