Int. J. of GEOMATE, Dec. 2011, Vol. 1, No. 2 (Sl. No. 2), pp. 95-98
Geotec., Const. Mat. and Env., ISSN:2186-2982(P), 2186-2990(O), Japan

Thermally Modifying Bentonite for Construction Industry

Abdoullah Namdar
Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang

ABSTRACT – The application of geology in civil engineering create possibility of ground improvement. This paper present thermally modification of construction material based on changing micro and macro characteristics. The heat can modify the soil shape, size and chemical composite as well as crystal structure. In this research work the bentonite subjected to the heat for 6 hours from 100 ºC to 500 ºC in increment of 100 ºC. The different techniques and methods have been used for changing soil micro and macro characteristics. And also the different technique validated this research investigation and the result has been shown that heat has significant affect on controlling geotechnical engineering problem. There is still more scope for continuing this research work on several natural soil and mineral in applying heat for different time and level for approaching better results.

Keyword: Soil characteristics; natural soil; ground improvement; geotechnical problem; soil atomic structure

1. INTRODUCTION

Clay has always played a major role in human life. Clay raw materials are used and their value recognized in many economic branches, agriculture, civil engineering and environmental studies. This is largely because of their wide ranging properties, high resistance to atmospheric conditions, geochemical purity, and easy access to their deposits near the earth's surface and low price.

Clay minerals, the essential constituents of argillaceous rocks, can be classified in seven groups according, to their crystal structure and crystal chemistry. Clay raw materials are divided in the same way into seven groups. An eighth group covers clay ochres and pigments. Further classification is based on the purpose-made technological application. It gives information on the application of clay raw materials or individual clay minerals: in the production of foods, feedstuffs, beverages, paper, rubber, plastics, artificial leather, protective coatings for interior and exterior use, pharmaceutics, cosmetics, paints, pencils, pastels, porcelain, etc [1]. There are many tests have been performed on bentonite for simulating compaction and densities [2-3]. It has been considered the engineering behavior of bentonite enhanced sand (BES) mixtures in relation to their performance as environmental barriers. At high effective stresses the bentonite has insufficient swelling capacity to force the sand particles apart, and the sand pore volume thus limits swelling [4]. Bentonite enhanced sand (BES) mixtures are widely used as barriers to control the movement of liquid from waste disposal facilities because BES can combine relatively high strength and low compressibility with very low hydraulic conductivity [5-6]. It has been reported on GMZ bentonite as a potential material for the construction of engineered barrier in the Chinese program of geological nuclear waste disposal, for its high montmorillonite content, high cation exchange capacity (CEC) and large specific surface etc. Studies on mineralogy and chemical composition, mechanical properties, hydraulic behavior, swelling behavior, thermal conductivity, microstructure and volume change behavior of GMZ bentonite were performed from 1980s [7]. There is requirement for construction of an engineered barrier around the waste containers [8]. Many other requirement are by several researcher are mentioned for application and important of modified materials but the bentonite thermally modified never has been investigated and It is also not known from the available literature, either from any experimental study or from the theory, about the effect of the heat on bentonite morphology, crystal structure and chemical composite in regarding its application in geotechnical engineering. The main objective of this research work is to modifying bentonite under laboratory condition using heat, and studying bentonite morphology, crystal structure and chemical composite and possibility of better using bentonite in construction industry.

2. METHODOLOGY AND EXPERIMENTS

In this research work a series experiments have been performed. The experimental were in the physics, material engineering and geotechnical engineering. The XRD, scanning electron microscopy (SEM), Tri-axial, density, optimum moisture content, natural moisture content and stress-strain relationship in different laboratory have conducted and the research is multidisciplinary research and gathering for application in civil engineering. The bentonite has been submitted to the heat for 6 hours in different from 100 ºC to 500 ºC in five different specimens. The main objective is to modifying construction material under laboratory condition using heat. The evaluation of both for the macro and micro of bentonite characteristics based on new research work and previous investigation[9] have been taken systematically trough of laboratory testing.

3. RESULTS AND DISCUSSION

The heat has been affected on soil mechanical behavior based on soil crystal structure and chemical composite and had significant affect on soil mechanical properties in macro and micro scale. In this investigation has been observed that the heat strongly changed soil mechanical properties. From the previous investigation in the table 1 is indicated unit weight, optimum moisture content and natural moisture content of bentonite.

Table. 1 the bentonite mechanical properties [9]

Heat ºC	γ (kN/m^3)	OMC (%)	NMC (%)
RT	12.1	42.4	13.43
100	12.2	42.5	9.46
200	12.3	42.77	8.9
300	12.1	42.3	5.3
400	11.6	39.2	2.53
500	11.5	38.8	2.33

Table. 2 the bentonite mechanical properties

Heat ºC	γ (KN/m^3)	C (KN/m^2)	Φ [◦]
RT	12.1	38	0
100	12.2	48	0
200	12.3	56	5
300	12.1	70	10
400	11.6	84	3
500	11.5	98	12

From this research work some other mechanical properties of bentonite has been mentioned in the table 2. The heat is playing in reducing bentonite unit weight and the interesting issue is the bentonite cohesive characteristic is increased linearly and from other hand the internal angle of friction is changing nonlinearly. It has been observed that the bentonite with new characteristic is with less weight and more bearing capacity. The changing bentonite crystal structure due to heat resulted in improved permeability. It can suggest that for increasing waterproof of soil foundation thermally treated bentonite can acceptable material.

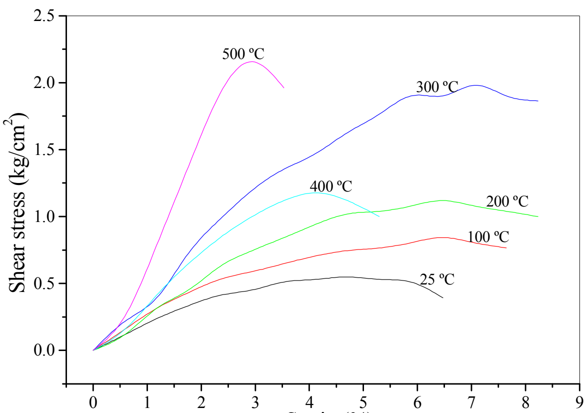

Fig 1 shear stress Vs strain in bentonite clay

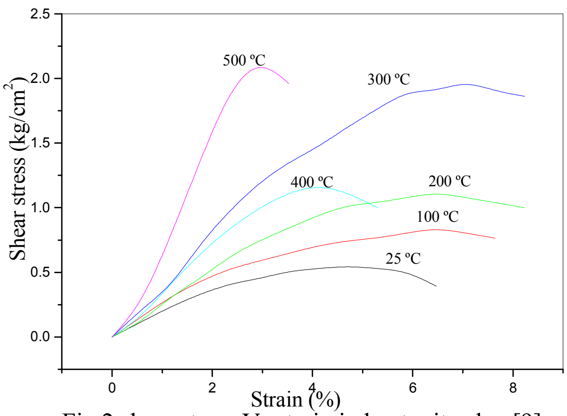

Fig 2 shear stress Vs strain in bentonite clay [9]

The soil mechanics experiment result has been shown that the best safe bearing capacity appeared when soil is subjected to 500 ºC heat, and the decreasing unit weight in this level has not affected on final result compare to when bentonite is under less heat level. In the room temperature bentonite has 700.06 kN/m^2 safe bearing capacity, when it is submitted to the heat for 500 ºC has been improved up to 3132.90 kN/m^2, it was understood that the application of heat on soils can helps in modification of construction material for improving earth structure stability and impermeability, and also can use in other industry. The fig 1 is stress-strain relationship of bentonite from triaxial test and the fig 2 is [9] also stress-strain relationship of bentonite from compression tests when subjected to different level of heat. The results of both methods are almost close to each other. When the heat is increased the stress-strain relationship increased but not linear and always increasing of heat not resulted in improving soil bearing capacity in this regard can bring example of bentonite is submitted to the 400 ºC.

This investigation was for applying heat on the bentonite up to 500 ºC and has also been limited for 6 hours. For the future investigation can extend the heat time and level in applying on bentonite, or other material for approaching better or optimizing result. For evaluation of changing bentonite mechanical properties subjected to the heat the chemical element and the morphology of the bentonite have also been investigated.

Table. 3 Chemical element of the bentonite subjected to heat

Heat ºC		O	Mg	Al	Si
25	Wt %	40.71	0.89	8.42	26.97
	At %	59.18	0.85	7.25	22.33
100	Wt %	40.91	-	8.34	26.79
	At %	59.68	-	7.22	22.27
200	Wt %	43.09	-	8.57	27.26
	At %	61.27	-	7.23	22.09
300	Wt %	36.29	-	8.05	28.17
	At %	55.41	-	7.28	24.50
400	Wt %	40.06	-	8.44	27.98
	At %	58.72	-	7.33	23.36
500	Wt %	39.65	-	9.21	27.67
	At %	58.29	-	8.03	23.17
		C	K	Ti	Fe
25	Wt %	1.12	1.90	2.68	16.84
	At %	0.73	1.13	1.30	7.01
100	Wt %	1.09	1.95	2.97	17.95
	At %	0.71	1.16	1.45	7.50
200	Wt %	1.14	2.11	2.82	15.01
	At %	0.73	1.22	1.34	6.12
300	Wt %	0.82	1.95	3.03	21.69
	At %	0.56	1.22	1.54	9.49
400	Wt %	0.93	1.73	2.50	18.36
	At %	0.62	1.04	1.22	7.71
500	Wt %	0.50	1.91	2.27	18.79
	At %	0.33	1.15	1.11	7.91

The table 3 indicated the chemical composite of the bentonite subjected to the heat and the XRF chemical analysis experiment has been indicated that the Mg and V of the bentonite have been disappeared after applying 100 ºC heat, and the from other hand the remaining elements which are O, Al, C, K, Ti, Si, Fe showing different level in changing heat level, and can understand that the chemical elements are not responsible for changing soil mechanical properties.

The scanning electron microscopy (SEM) analysis have clearly revealed that the surface morphology, shape and size of the minerals (figs 3-8). The bentonite under heat for 6 hours from 100 ºC to 500 ºC in increment of 100 ºC selected to study its morphology modification, the result shown that under all conditions results are closely similar (fig 3-8) and also same result is observed about soil chemical composite from the XRF experiment (table 3) it can expected that the soil crystal structure is main reason in modification of soil mechanical properties. It is observed different color of bentonite at any level of heat is applied. The changing bentonite color during increasing heat is due to modification of crystal structure of bentonite. It is to be noted that innovation of the better construction material is possible by application of the heat on bentonite. It is interesting to be mention that in the bentonite submitted to the heat for 500 ºC after return to room temperature when mixed with the water to carry out of compaction test the small hydration has been observed. It is due to developed new bentonite characteristic based on changing crystal structure. The modification of crystal structure was responsible for improving bentonite mechanical properties.

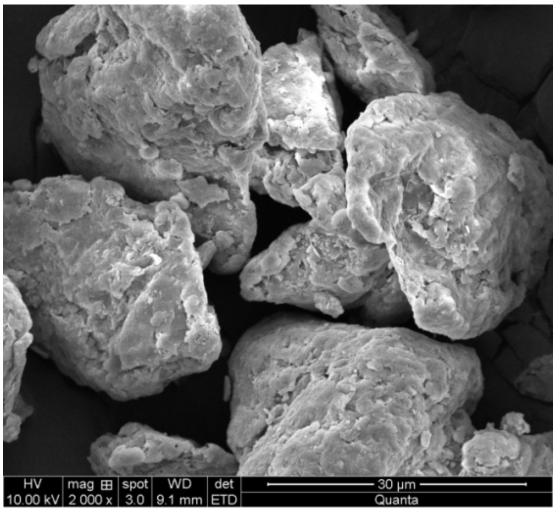

Fig. 3 SEM Photo of bentonite at 25 ºC

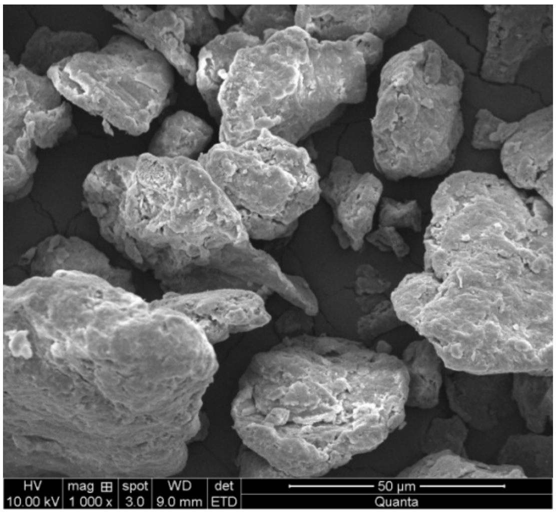

Fig. 4 SEM Photo of bentonite processed under 100 ºC for six hours

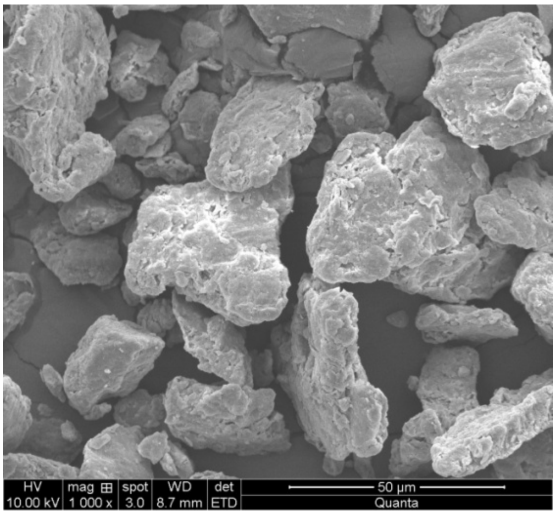

Fig. 5 SEM Photo of bentonite processed under 200 ºC for six hours

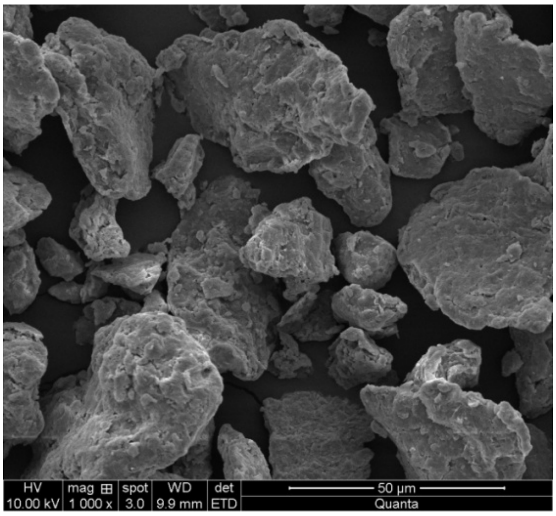

Fig. 6 SEM Photo of bentonite processed under 300 ºC for six hours

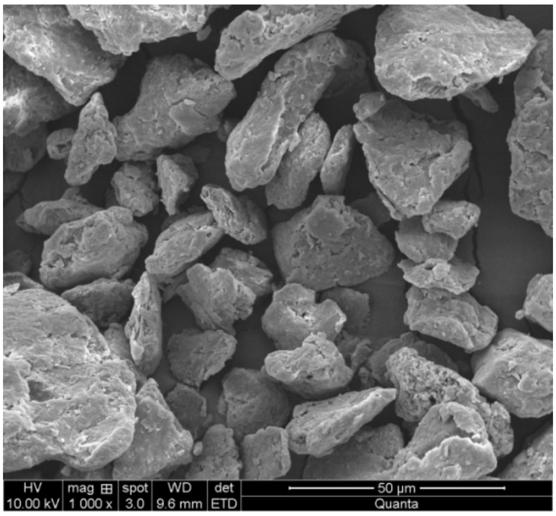

Fig. 7 SEM Photo of bentonite processed under 400 ºC for six hours

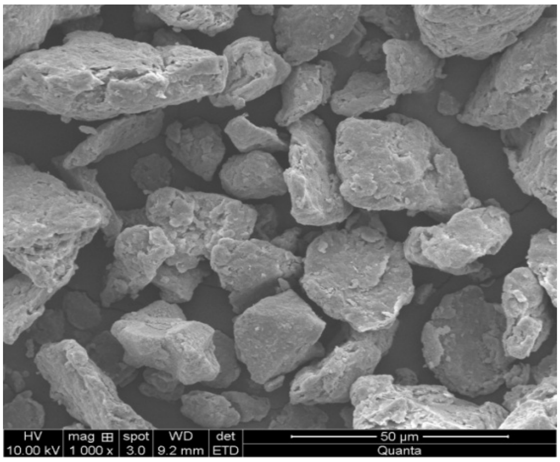

Fig. 8 SEM Photo of bentonite processed under 500 ºC for six hours

4. CONCLUSION

- The results have been comparing to previous investigation [9] and the bentonite crystal structure rearrangement controlled specimen engineering properties
- The bentonite morphology not plays any role in engineering properties of specimen.
- This method can apply for different materials for approaching better results

5. ACKNOWLEDGEMENTS

The author would like to express his thanks to faculty of civil engineering, SJCE, Mysore, India, and faculty of earth science of University of Mysore, India for timely guidance.

6. REFERENCES

[1]. Ji i Konta, Clay and man: clay raw materials in the service of man, Applied Clay Science, Vol. 10, 1995, pp. 275-335.

[2]. Martín, M., Cuevas, J., Leguey, S., Diffusion of soluble salts under a temperature gradient after the hydration of compacted bentonite, Applied Clay Science, Vol. 17, 2000, pp. 55–70.

[3]. Villar, M.V., Sánchez, M., Gens, A., Behaviour of a bentonite barrier in the laboratory: experimental results up to 8 years and numerical simulation. Physics and Chemistry of the Earth, Vol. 33, 2008b, pp. 476–485.

[4]. D.I. Stewart, P.G. Studdsb, T.W. Cousens, The factors controlling the engineering properties of bentonite-enhanced sand, Applied Clay Science, Vol. 23, 2003, pp. 97 – 110.

[5]. Tay, Y.Y., Stewart, D.I., Cousens, T.W., Shrinkage and desiccation cracking in bentonite – sand landfill liners, Engineering Geology, Vol. 60, 2001, pp. 263 – 274.

[6]. Yong, R.N., Soil suction and soil – water potentials in swelling clays in engineered clay barriers, Engineering Geology, Vol. 54, 1999a, pp. 3 – 13.

[7]. Wei-Min Ye, Advances on the knowledge of the buffer/backfill properties of heavily-compacted GMZ bentonite, Engineering Geology, Vol. 116, 2010, pp. 12-20.

[8]. Villar, M.V., Lloret, A. Influence of dry density and water content on the swelling of a compacted bentonite., Applied Clay Science, Vol. 39, 2008, pp. 38–49.

[9]. Abdoullah Namdar, et al, Bentonite Thermal Behavior in Geotechnical Engineering, International Journal of Engineering, Vol. 4, 2011 ,pp. 83-86.

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
NMC (%)	= Natural Moisture Content

International Journal of GEOMATE , Dec. 2011, Vol. 1, No.2 (Sl. No. 2)
MS No. 2b received Dec.1, 2011, and reviewed under GEOMATE publication policies.

Corresponding Author: Abdoullah Namdar