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BENTONITE THERMAL BEHAVIOR IN GEOTECHNICAL ENGINEERING

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ABSTRACT: The thermal applied on the soil is one of the important external elements for changing soil mechanical characteristics based on mineralogy and stress-strain relationship. To evaluation of bentonite clay behavior when subjected to the thermal, several laboratory tests have been conducted to analysis of bentonite characteristics. In this research work the thermal on each specimen is applied for 6 hours from 100 °C to 500 °C in increment of 100 °C, it is for considering of mineralogy and mechanical properties of bentonite to development a better construction material. The result revealed the structural atomic and chemical compoiste of the bentonite changed when it is submitted to the thermal and it could be main reason of changing soil mechanical behavior, and also using accurate thermal advantage leads to developing a construction material with new and desirable mechanical properties. It is helps in safe designing and constructing of earth structure, soil foundation or any others earth works.

KEYWORDS: Temperature; Mineralogy; Stress; Strain; Soil Testing

❖ INTRODUCTION

To achieve stability of structures needs to improve construction material quality based on economically and feasibility methods. It could be done by several techniques and methods, the use of thermal element could be one of the acceptable methods.

There is investigation on thermal conductivity, thermal resistivity, thermal diffusivity and volumetric heat capacity of the mud samples collected from both the tidal flat and inside the deep sea was measured in the laboratory [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 report on the determination of the effect of Additives on the thermal Conductivity of clay [3]. It has also been reported affect of temperature on oscillatory shear behavior of portland cement paste incorporating chemical admixtures [4]. Due to very meager investigation on construction material submitted to the thermal the authors made an attempt using positive advantage of thermal for improving soil quality in construction industry, in this regard analysis of bentonide stress-strain at any temperature from 100°C to 500°C in increment of 100 °C have been executed to achieving acceptable construction material quality and also this research could be extended for other construction materials.

❖ METHODOLOGY AND EXPERIMENTS

To understand of the material behavior in the geotechnical engineering, it was decided to perform of a series experiments in the case of a construction material submitted to thermal in the different level of temperature for six hours from 100°C to 500°C in increment of 100°C. The main objective of the experiment was to analyze of the soil thermal reaction mechanism in the laboratory condition. The measurements of both for the macro and micro bentonite characteristics have been taken systematically trough of laboratory testing in the geotechnical laboratory of National Institute of Engineering, Mysore, India and physics laboratory of Physic Department, University of Mysore, and Mysore, India. In the soil testing laboratory compression, compaction and permeability tests conducted and in the physic laboratory X-ray diffraction have been executed. The density, optimum moisture content, natural moisture content and stress-strain relationship of the bentonite based on thermal application and mineralogy have been analyzed.

❖ RESULTS AND DISCUSSION

The several theoretical and computational research works executed to improvement and innovation of better construction material based on quality, economically and feasibility. It is clearly understood the bentonite characteristics will change when it is under elevation thermal, it is also not known from the available literature, either from any experimental study or from the theory, about the affect of the thermal on the magnitudes changing bentonite mechanical properties.

Table 1. The bentonite mechanical properties

Model No	Temperature °C	γ_d (gr/cc)	Optimum Moisture Content	Natural Moisture Content
1	RT	1.21	42.4	13.43
2	100	1.22	42.5	9.46
3	200	1.23	42.77	8.9
4	300	1.21	42.3	5.3
5	400	1.16	39.2	2.53
6	500	1.15	38.8	2.33

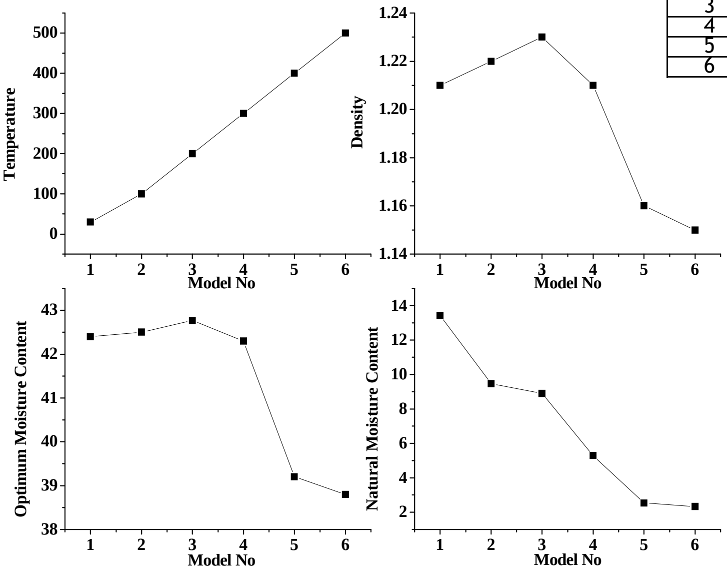

Figure 1. Model No vs Temperature, density, OMC and NMC

It is aimed to perform a series of the soil mechanic tests on bentonite under elevation thermal from 100°C to 500°C in increment of 100°C on assessment of the mechanical properties behavior of the bentonite. The purpose of the entire research exercise would be to (i) predict the response of the bentonite subjected to an elevation thermal, and (ii) formulate some useful guidelines to improvement of soil foundation using modified bentonite under thermal elevation.

The table 1 and figure 1 indicated that the due to increasing of thermal in processing material characteristics modification when thermal is increased that could observed increasing density up to 300°C and from this point density is decreased and minimum of density could be find in the 500°C it is a new material with maximum of the shear strength, in application of thermal on this material could reached a new material with maximum strength and minimum of weight compare to unmodified bentonite.

The deformation per unit length is called strain. The residual stress can be introduced by any mechanical, chemical or thermal methods. The principal of stress analysis by the x-ray diffraction is based on measuring angular lattice strain distributions. That is, we choose a reflection at high 2-Theta and measure the change in the d-spacing with different orientations of the sample. Using Hooke's law the stress can be calculated from the strain distribution [5].

The crystal unit cell of six samples have been evaluated [figures 2-7 and tables 2-7], and based on structural atomic and chemical composite could be mention the that bentonite when it is under 400 and 500 °C temperature and with result of almost similarity in the chemical composite, due to higher unit cell volume of bentonite crystal at 400 °C the less stress strain appeared.

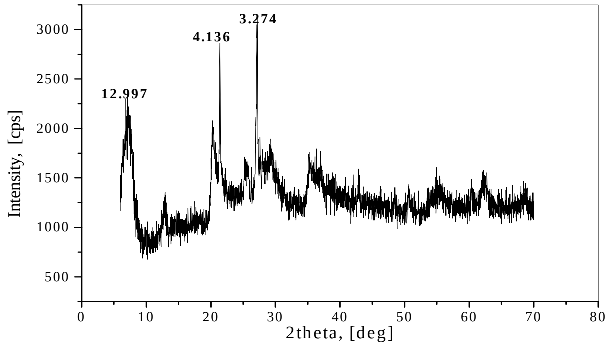

Figure 2. Intensity vs. 2theta at 25^0C

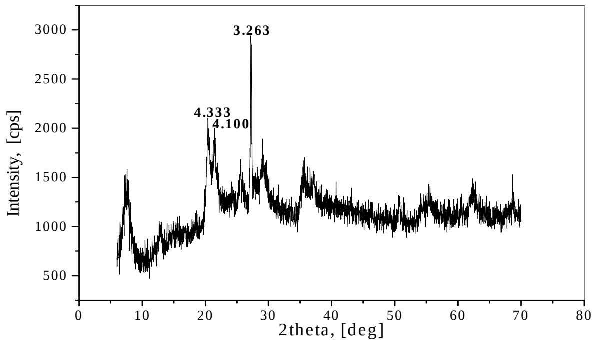

Figure 3. Intensity vs. 2theta at 100^0C

Table 2 XRD analysis of bentonite in room temperature

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
1	1	1	0.031056	0.031109	-0.000054	20.300	20.318	4.3711
2	0	0	0.034472	0.034649	-0.000177	21.400	21.456	4.1488
2	0	1	0.048407	0.048434	-0.000027	25.420	25.427	3.5011
0	0	2	0.054973	0.055139	-0.000165	27.120	27.162	3.2854
1	0	2	0.063965	0.063801	0.000164	29.300	29.261	3.0457
3	0	1	0.091830	0.091746	0.000084	35.280	35.263	2.5419
A =8.276395A B =8.276395A C =6.560874A	ALFA = 90.00 DEG BETA = 90.00 DEG GAMMA = 90.00 DEG	UNIT CELL VOLUME = 449.41 A**3						

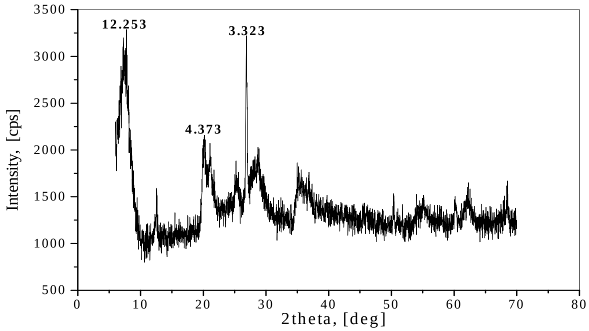

Figure 4. Intensity vs. 2theta at 200^0C

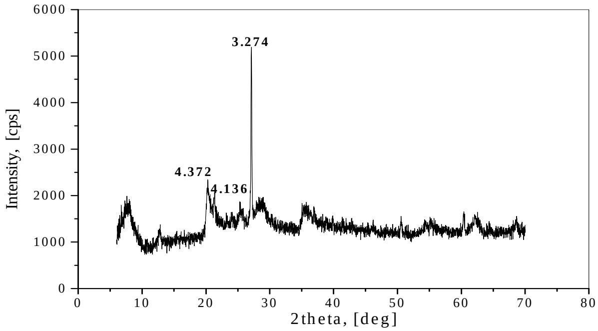

Figure 5. Intensity vs. 2theta at 300^0C

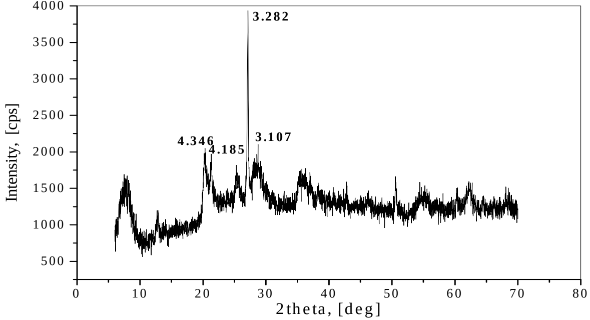

Figure 6. Intensity vs. 2theta at 400^0C

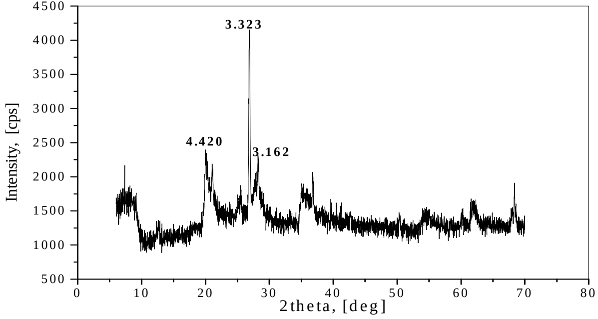

Figure 7. Intensity vs. 2theta at 500^0C

Table 3 XRD analysis of bentonite under 100 ºC for 6 hours

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
1	0	0	0.004346	0.004348	-0.000001	7.560	7.561	11.6844
0	2	0	0.031481	0.031481	-0.000001	20.440	20.440	4.3415
2	2	0	0.048783	0.048872	-0.000089	25.520	25.544	3.4876
0	2	1	0.055451	0.055446	0.000006	27.240	27.239	3.2712
3	0	1	0.063029	0.063093	-0.000064	29.080	29.095	3.0682
4	0	1	0.093247	0.093526	-0.000280	35.560	35.615	2.5226
4	1	1	0.101735	0.101397	0.000338	37.200	37.136	2.4150

A = 11.682440A ALFA = 90.00 DEG UNIT CELL VOLUME =504.74 A**3
B = 8.682841A BETA = 90.00 DEG
C = 4.975943A GAMMA= 90.00 DEG

Table 4 XRD analysis of bentonite under 200 ºC for 6 hours

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
0	2	0	0.030513	0.030504	0.000009	20.120	20.117	4.4098
2	1	0	0.033523	0.033648	-0.000125	21.100	21.140	4.2071
0	0	1	0.047735	0.047710	0.000025	25.240	25.233	3.5257
1	0	1	0.054101	0.054216	-0.000114	26.900	26.929	3.3117
3	0	0	0.058608	0.058550	0.000058	28.020	28.006	3.1819
1	1	1	0.061931	0.061842	0.000089	28.820	28.799	3.0953

A = 9.550316A ALFA = 90.00 DEG UNIT CELL VOLUME =297.09 A**3
B = 8.820868A BETA = 90.00 DEG
C = 3.526586A GAMMA= 90.00 DEG

Table 5 XRD analysis of bentonite under 300 ºC for 6 hours

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
1	0	0	0.004769	0.004760	0.000009	7.920	7.912	11.1541
2	1	0	0.031056	0.031089	-0.000034	20.300	20.311	4.3711
0	0	1	0.043583	0.043629	-0.000046	24.100	24.113	3.6898
1	0	1	0.048407	0.048389	0.000018	25.420	25.415	3.5011
3	1	0	0.054894	0.054891	0.000003	27.100	27.099	3.2877
2	0	1	0.062690	0.062670	0.000020	29.000	28.995	3.0765
0	2	1	0.091830	0.091823	0.000008	35.280	35.278	2.5419

A = 11.164650 0.003701A ALFA = 90.00 DEG UNIT CELL VOLUME = 288.94 A**3
B = 7.017690 0.002562A BETA = 90.00 DEG
C = 3.687840 0.000777A GAMMA=90.00 DEG

Table 6 XRD analysis of bentonite under 400 ºC for 6 hours

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
1	1	1	0.030935	0.030920	0.000014	20.260	20.255	4.3796
0	2	0	0.034154	0.034212	-0.000058	21.300	21.318	4.1681
3	2	0	0.048407	0.048270	0.000137	25.420	25.383	3.5011
0	2	1	0.054894	0.055017	-0.000124	27.100	27.131	3.2877
5	1	1	0.068302	0.068408	-0.000106	30.300	30.324	2.9474
0	1	2	0.091830	0.091774	0.000057	35.280	35.269	2.5419
3	0	2	0.097139	0.097279	-0.000139	36.320	36.347	2.4715
6	3	0	0.133254	0.133210	0.000044	42.820	42.813	2.1102
4	4	1	0.182635	0.182646	-0.000011	50.600	50.602	1.8025

A =19.490300A ALFA =90.00 DEG UNIT CELL VOLUME =866.94 A**3
B =8.329109A BETA =90.00 DEG
C =5.340403A GAMMA=90.00DEG

Table 7 XRD analysis of bentonite under 500 ºC for 6 hours

H	K	L	SST-OBS	SST-CALC	DELTA	2TH-OBS	2TH-CALC	D-OBS
2	1	0	0.030393	0.030397	-0.000004	20.080	20.081	4.4185
1	2	0	0.033460	0.033418	0.000043	21.080	21.066	4.2111
0	0	1	0.048632	0.048607	0.000025	25.480	25.473	3.4930
3	1	0	0.059513	0.059787	-0.000274	28.240	28.306	3.1576
2	2	1	0.099634	0.099659	-0.000025	36.800	36.805	2.4404
7	2	0	0.315613	0.315561	0.000052	68.360	68.354	1.3711

A =10.047200A ALFA =90.00 DEG UNIT CELL VOLUME = 325.88 A**3
B =9.283422 A BETA =90.00 DEG
C =3.493884 A GAMMA=90.00DEG

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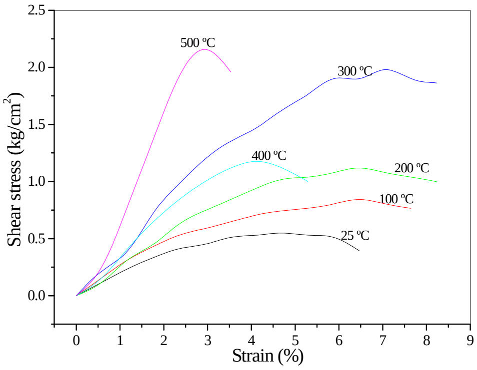

Figure 8. Shear stress vs. strain in bentonite clay

Table 8. Shear stress – strain of bentonite from compression tests

Strain	Shear Stress					
	At 25 °C	At 100 °C	At 200 °C	At 300 °C	At 400 °C	At 500 °C
0.58824	0.11764	0.15686	0.11764	0.21568	0.15686	0.25489
1.17647	0.23529	0.31372	0.31372	0.39214	0.41175	0.78429
1.76471	0.33332	0.43136	0.45097	0.72547	0.64704	1.3725
2.35294	0.41175	0.52939	0.62743	0.98036	0.84311	1.92151
2.94118	0.45097	0.58822	0.74507	1.19604	0.99997	2.15679
3.52941	0.50979	0.64704	0.84311	1.3529	1.11761	1.96072
4.11765	0.52939	0.70586	0.94115	1.47054	1.17643	
4.70588	0.549	0.74507	1.01957	1.6274	1.11761	
5.29412	0.52939	0.76468	1.03918	1.76465	0.99997	
5.88235	0.50979	0.8039	1.0784	1.9019		
6.47059	0.39214	0.84311	1.11761	1.9019		
7.05882		0.8039	1.0784	1.98033		
7.64706		0.76468	1.03918	1.9019		
8.23529			0.99997	1.86268		

It was expected of strain stress relationship in the bentonite when it is under 400°C temperature be higher than when this is under 300°C, 200°C, 100°C and 25°C but these series experimental indicated that the structural atomic of crystal play main factor in strength of material, and strength of material modification is possible trough the achieving appropriate structural atomic of material and it is applicable using thermal advantage [table 8 and fig 8].

It is to be noted that the better construction material innovation is possible by application of the thermal on bentonite. It is interesting to be mention that in the bentonite submitted to the 500°C when mixed with the water to carry out of compaction test the hydration has been observed. It is due to developed new mineral by application thermal on the bentonite.

The permeability experiment indicated that the bentonite remains impervious at all time but the table 1 and figure 1 indicated that the nature and optimum moisture content are decreased, and it may reduces permeability strength of bentonite.

❖ CONCLUSION

- The bentonite chemical composite and structural atomic were changed when thermal applied it was started from 100°C
- The application of 500°C thermal resulted in achieving new material with maximum strength and minimum of weight
- In the two bentonite crystal when the chemical composite is close similar structural atomic play main factor in the strength of material and strain stress relationship for example when the bentonite is under 400 and 500°C temperature
- The permeability experiment indicated that the bentonite remains impervious at all experiments form 25°C to 500°C

❖ NOMENCLATURE

Φ [°] = Friction Angle; C [kN/m2] = Soil Cohesivity; RT = Room Temperature; γ_d (gr/cc) = Density (gr/cc); OMC% = Optimum Moisture Content ; NMC% = Natural Moisture Content

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