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MICROSCOPIC AND CLUSTERING ANALYSIS OF KAOLIN BASED GEOPOLYMER LATERITICS SOIL. A CASE STUDY OF NORTH-CENTRAL NIGERIA

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ABSTRACT
The strength of a fine-grained lateritic soil from three (3) different localities on Abuja – Lokoja road where road failure happen was treated with rice husk ash (RSA), cement and sodium silicate activator (SSA), with varying percentage examined by means of Atterberg, Compaction and triaxial shear tests. Conductivity has the highest mean (144.67mg/l) and followed by total dissolved solid (TDS) (94.00mg/l) while salinity recorded the lowest (0.06mg/l). Also, TDS recorded the highest Standard deviation (1.10mg/l).
KEYWORDS: ***Geopolymer, Cluster, Construction, Sodium silicate, Abuja.***

1.0 INTRODUCTION

Majority of the road failures are normally reported as outcome of traffic overloading and environmental influences, distress investigations reveal that most of the road failures in Nigeria develop prematurely due to the use of substandard construction materials, poor construction techniques and soil conditions [1-3]. Subgrades are commonly compacted before the construction of a road [4-5], pavement or railway track [6], and are sometimes stabilized by the addition of asphalt, lime, portland cement or other modifiers [7-9]. The subgrade is the foundation of the pavement structure, on which the subbase is laid down. Laterites vary in color, but are usually brightly colored [10-13]. The shades most frequently encountered are pink, ochre, red and brown; however, some occurrences are mottled and streaked with violet, and others exhibit green marbling[14-17]. A single sample may exhibit a whole range of colors merging more or less perceptibly into one another in a variety of patterns and forms. Laterites owe their color to iron oxides in various states of hydration and sometimes also to manganese [18-20]. Their mineralogy generally involves quartz, kaolinite, hematite, goethite, and sometime maghemite. Kaolinite is always present with iron oxides [21-24]. The physical properties of lateritic soil vary according to the mineralogical composition and particle size distribution of the soil [25-27]. Stabilization technique has been a concern to transportation planners and designers for the past decade as alternatives to cut off or scrap unsuitable materials when encountered on site [28-30]. An alteration to the physical or engineering properties of a soil mass will require investigation of economic alternatives such as relocation of the site or use of borrowed materials [31-33]. At present, most of the desirable building sites near urban areas have been used making alternative location not practical.Geopolymer is a product of the alkali activation of aluminosilicate materials present in industrial waste materials such as furnace slag, slag furnace, granulated blast-furnace slag, fly ash, kaolin clay and red mud [34-38]. Geopolymer like ground granulated blast-furnace slag (an industrial waste produced from the cement production) and kaolin clay (natural occurring waste). Whereas rice husk fibre is waste from agricultural. Besides, globally, ground granulated blast-furnace slag and rice husk fiber produced by cement factories and rice industries have been increasing for the past few years. The mass production of both ground granulated blast-furnace slag and rice husk fiber causes disposal problems and an increase in expenses for storage in available landfills. This eventually poses a threat to the environment if it is not properly managed. The use of geopolymeric materials in setting soil improvement is growing daily [39-42]. Unfortunately, little research has been completed to distinguish between products that deliver enhanced performance and those that do not [43-47]. The nature of soil stabilization dictates that products may provide soil-specific properties and/or provide compatibility with environment. In other words, some products may work well in specific soil types in a given environment but perform poorly when applied to dissimilar materials in a different environment [5-6,48-49]. The use of geopolymer materials as soils stabilizers has been widely studied and results of such past studies indicate that geopolymers could be used as an effective soil stabilizer.

2.0 LITERATURE REVIEW

2.1 Concept of water

Globally, it is expected that land and water resources will continue to develop, since majority of the surface water bodies like streams, rivers etc. interact with groundwater [50]. Some interactions include: discharge of groundwater (containing solutes) into surface water features and groundwater recharge by surface water bodies causes variations in groundwater quality. With a rapid population growth, urbanization, contamination and contributions from the air through the burning of biomass materials induce environmental deterioration, especially dangers on water supplies due to microbial and chemical pollutants will definitely rise [51-53]. Waste disposed at dumpsites, burning of waste materials and storm water runoff carry contaminants to nearest ground and surface water sources.Determining the concentration of pollutants (by comparing measured parameters with international standards) and evaluating the level of pollution of water supply are conducted to examine the impact of quality control measures on water quality.

2.2 Multivariate concept

The multivariate statistical analysis is a technique which deals with data that comprises of sets of measurements or a number of variables (individuals or objects) as observed [52]. Its analysis is to clearly reveal the governing processes through reduction and grouping of a given data. Multivariate approach is regarded as a very useful tool for dealing with the increasing number of parameters that affect water quality. They have been applied in many areas of research work, such as, surface water quality assessment [53-55]; to evaluate the parameters involved in surface-groundwater relationship (hydrogeochemical) as suggested [56] and[57]. Multivariate analysis can aid simplification and classification of large data sets and are also useful for drawing significant deductions as observed [58]. Factor and Cluster analyses are few of the common and efficient ways of showing complex relationships among many variables (objects) as stated by [56]. Among the multivariate statistical techniques, the hierarchical cluster analysis (HCA) and principal components analysis (PCA) are mainly used in water quality studies. In cluster analysis (CA), the data cluster is divided into groups in terms of the similarities and differences, and the dimensionality of a data cluster is degraded to a new variable group via the principal components analysis [52-54]. The systemsmonitor the time-based changes in water systems, and to obtain useful findings. application of different multivariate approaches (cluster analysis (CA, principal components analysis, source apportionment by multiple regression on principal components) for the interpretation of these complex data, matrices offers a better understanding of water quality and ecological status of the studied systems and allows the identification of the possible factors/sources that influence the water systems and offers a valuable tool for reliable management of water resources as well as rapid solutions on pollution problems [51,57].

2.3 Microstructure analysis

X-ray diffraction (XRD) is a nondestructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of materials [46-47]. *XRD* is a powerful nondestructive technique for characterizing crystalline materials. It provides information on structures, phases, preferred *crystal* orientations (texture), and other structural parameters, such as average grain size, crystallinity, strain, and *crystal* defects [48-49]. Scanning electron Microscopy (SEM)is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons[46.48]. The electrons interact

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with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image

3.0 ANALYSIS RESULTS

3.1 Descriptive Statistics

Table 1and Figure 1shows the result of the physical parameters of water utilized for geopolymer analysis. The result showed that Conductivity has the highest mean (144.67mg/l) and followed by total dissolved solid (TDS) (94.00mg/l) while salinity recorded the lowest (0.06mg/l). Also, TDS recorded the highest Standard deviation (1.10mg/l).This was followed by total suspended solid (TSS) (0.75mg/l) while salinity recorded the least value of (0.006mg/l). Thus,all the parameter of all the water samples examined are within the maximum permissible limit of Federal Ministry of works and Housing standards for construction water quality.

3.2 Cluster Analysis (Using Squared Euclidean distance)

Result from Table 2which were graphically represented in Figures2&3detect similarity groups between the lateritic soils and geopolymer. Two statistically significant clusters are formed for AtterbergC1 and C2, which yielded two groups of similarity between the sampling sites. CBR, compaction, UCS and Triaxial test represented are presented as A and B.Temporal cluster analysis was used on standardized log-transformed data sorted by season. CA was performed using squared Euclidean distances as a measure of similarity.

3.3 Impact of Correlation Analysis (Atterberg limit, compaction, CBR and UCS)

The laboratory experimental results analysis forthis research work was carried out usingCorrelation analysis as the primary statistical tooland statistical package for social science (SPSS)as statistical software packages for statisticalanalysis.Correlation analysis is a statistical technique toquantify the dependence of two or morevariables. The purpose of a correlationanalysis is to determine whether there is arelationship between sets of variablesCBR,RHA, and OMC or UCS, RHA, and OMC and the Outcomes of correlation are summarized in Table 3&4 and Figure 4.Inference was based on the strength tests(CBRsoakedand UCS) results gotten from cement, RiceHusk Ash (RHA), kaolin clay powder and geopolymer mix stabilized soil other than thoseobtained from RH.Each of the parameters pair were calculated using Pearson's correlation coefficients as displayed in Table 5. A significant correlation was found to exist between Geopolymerand Kaolin clay powder ($r = 0.95$, $\alpha = 0.05$).

3.3.1 Correlation analysis for unconfined compressive strength

Regression analysis predict the interaction between sets of variables (one or more) called independent variables and a single variable called dependent variable. Researches in sciences and engineering have applied regression analysis to buttress relationships between two variables or sets of variables [13-15]. The regression plot indicates that all the parameters considered have influence on the UCS values of stabilized soil. The coefficients of regression for each parameter would reveal the level of the effect of the parameter on the UCS. KCP, RHA and OMC have positive coefficients which depict the fact that increase in these parameters lead to improvement in UCS of the compacted soil Table 3. Similarly, the MDD, PF, PI and CE have negative coefficients, which depict decrease in UCS with increase in these variables. Care should be taken to ensure these variables are properly controlled at the site during field compaction to achieve a durable road pavement.

3.3.2 Correlation analysis for California bearing ratio

Regression analysis result for California bearing ratio are presented in Figure4and Table 4. Result of regression analysis show that all the parameters considered have effect on the CBR of the treated soil with correlation coefficient value of R2 = 92.7 %. The coefficients of each parameter reveal the magnitude of the effect of the parameter on the CBR. MDD have positive coefficients which depict the fact that increase in these parameters will lead to improvement in CBR of the compacted soil. Similarly, the OMC, PF, PI and CE have negative coefficients, which depict decrease in CBR with increase in these variables.

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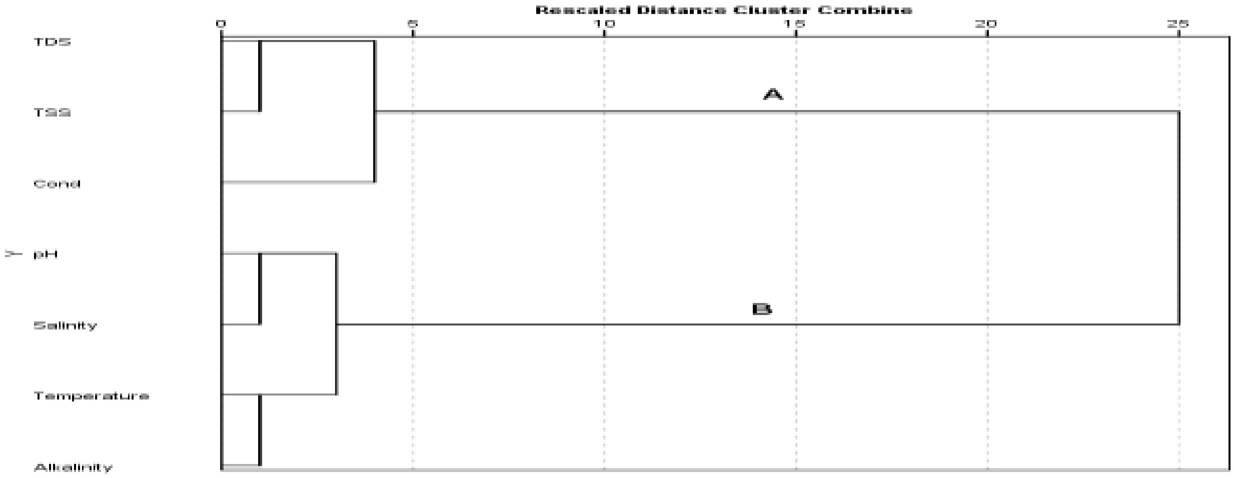

Figure 2: Dendogram for water test.

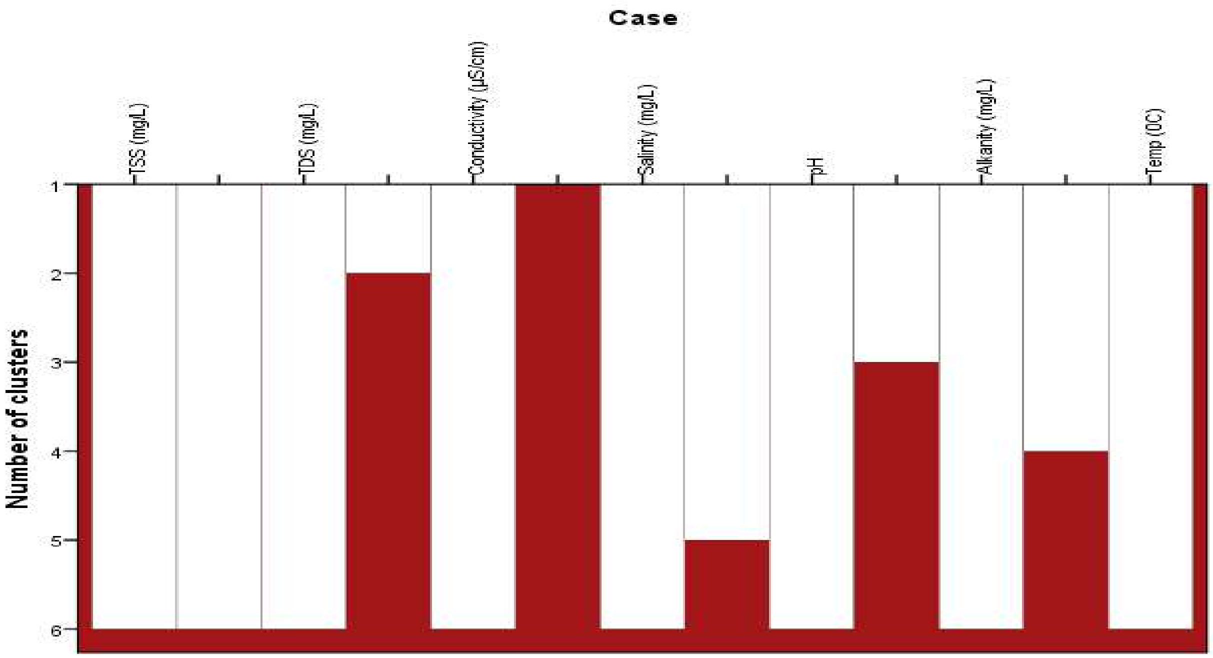

Figure 3: Numbers of clusters for water test

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Table 2: Agglomeration schedule of Cluster Analysis (Water Test)

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	4	5	17.500	0	0	5
2	2	7	136.942	0	0	4
3	1	6	2199.817	0	0	4
4	1	2	10272.836	3	2	6
5	3	4	20986.002	0	1	6
6	1	3	101760.520	4	5	0

Table 3: Relationship between UCS, cement, RHA, KCP and OMC (H_1: there is significant relationship between, CBR, OMC and geopolymer).

Variable	N	Mean	Std Dev	r-cal	P-value	Remark
Stabilizer	6	441.97	191.88			
Cement	6	64.06	21.63			
RHA	6	74.07	25.21	0.980	0.003	Reject H_0
KCP	6	358.20	145.04			

Table 4: Relationship between CBR, cement, RHA, KCP and OMC (H_0: there is significant relationship between, CBR, OMC and geopolymer).

Variable	N	Mean	Std Dev	r-cal	P-value	Remark
Stabilizer	6	92.91	46.19			
Cement	6	32.73	14.25			
RHA	6	71.83	32.90	0.998	0.002	Reject H_0
KCP	6	76.65	37.29			

3.5 Effect on X-ray diffraction, XRF, SEM, EDAX and FITR.

3.5.1 Effect on X-ray diffraction

The effect of addition of additives on the soil structurehas been observed by X-ray diffractiontest. Figure5shows the XRD patterns for natural andchemically treated laterite soil. XRD technique was used toachieve two goals: first, involving the measurement ofmineralogical changes of soil structure due to the presenceof liquid stabilizer, and secondly, to find newly formedcrystalline cementitious compounds. A Bruker D8 advancediffractometer was employed for the analysis of curedsamples. The Cu-Ka radiation (k = 1.54 A °) at an anglescan (2h) of 6–90_, step size of 0.02_, and 1 s lodging ateach step was used for scanning. The high resolutionimages of fabric of the soil prior and after the treatmentwere captured by a SEM that was equipped with EDAX. Inorder to prepare the samples, they were completely coveredby platinum under highly vacuum environment. Moreover,the EDAX method was used to find the major elementalcomposition on the surface of treated particles. The resultswere presented based on the ratios of Al:Si and Na:Si atvarying time intervals. The analysis of FTIR was appliedon treated samples to determine their molecular structuralchanges. In order to measure the absorption bands of theprepared KBr disk, a 2 mg sample of grounded dried soilwas mixed with 200 mg KBr. The sample was scanned bya Perkin Elmer Spectrum 2000 gadget in the400–4,000 cm-1 infrared spectrum range[47].A comparison was made between the resultant patterns and the standard datasetfrom Joint Committee for Powder Diffraction Standards[49]. This figureexplains that the new structure soil has been appearedin soil stabilized with 4% cement, KCP and geopolymer, and 20% RHA.Presence of the analcite and carbonate at peak 3.43and 3.30 A ˚ exhibits a reaction processed. This impliesthat pozzolanic reaction is taking a place to form acementitious material. The peak of quartz (3.34 A ˚)and feldspar (6.14 A ˚) has been disappeared at stabilizedresidual soil.

The main existed minerals in the laterite soil specimens were kaolinite and gibbsite [46-48]. Comparisons of the XRD results for the treated and untreated samples showed that quartz was unaffectedby the treatment. However, there was a noticeablechange in the XRD results for the kaolinite spectra. Generally,in all of the treated samples, few peaks werediminished and reduced slightly. This was because of thestabilizer effect and its weathering action on the clay minerals. However, no new peaks due to the gel-form(amorphous) structure of formed reaction products wereobtained [47-49].

3.5.2 Effect onXRF

The impact of addition of additives on the soil structurehas been observed by X-ray fluorescent test. Figure 6 shows the XRF patterns for natural andchemically treated laterite soil. XRF (X-ray fluorescence) is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) X-ray emitted from a sample when it is excited by a primary X-ray source.

3.5.3 Effect on SEM

Micro-analyses of the treated samples in the SEM werealso performed at different time intervals. Figure 7present the SEM results of untreated and treated soilsamples. The existence of free oxides within the untreatedsoil covered and bonded the soil particles togetherin a big packet fabric. On the other hand, the formationof new white layers of reaction products on the surface oflateritc soil particles samples is evident. These compoundswere roughly identified as sodium aluminosilicate hydrate(N–A–S–H) [46-48].

3.5.4 Effect on FTIR

The FTIR analysis is used to measure the absorptionbands at characteristic wavelengths of bonds that vibrateindependently of one another in order to define the functionalgroups of soil minerals. Figure8shows the FTIR spectrumsfor the natural and chemically stabilized samples. Thecommon features of FTIR spectrums involved the followings:the bands at 1,111 and 1,028 cm-1 indicated the perpendicularand in-plane Si–O stretching, respectively. Thepeaks at 3,615 cm-1 corresponded to inner OH-stretchingvibrations and band at 3,692 cm-1 was inner-surfacehydroxyl groups [47]. The latter was atypical band of kaolinite mineral, while the former was acharacteristic of various phyllosilicate minerals. Moreover,the band at 910 and 792 cm-1 indicated the existence ofhematite, respectively [48,49]. The other bands including the Si–Ovibrations observed at 535, and 466 cm-1 mostly defined theexistence of kaolinite mineral. A stretching vibration wasidentified at 3,446 cm-1, while the 1,637 cm-1 band was anH–O–H flexible band of water with an overtone happening at3,378 cm-1. The results of FTIR spectrum for 7, and 14 days cured samples confirmed that the chemical treatment was able to make a noticeable difference in the Si–O functional groups of soil particles. Also, in general thepeaks intensities reduced with curing time. This was becauseof the weathering action of the stabilizer on the clay minerals[46-49].

CONCLUSION

Two statistically significant clusters are formed A and B, which yielded two groups of similarity between the three lateritic soil and the geopolymer materials.The statistical analysis for CBR and UCS shows a positive correlation (between the CBR, RHA and the OMC which indicate a direct relationship between the variables.A significant correlation was found to exist between Geopolymer and Kaolin clay powder ($r = 0.95$, $\alpha = 0.05$). Also, it was found that for the samples treated with higher liquid stabilizer content (more than 8 % SSA) a lower compressive strength was achieved. The latter was probably due to the increase in the positive surcharge and the subsequent repulsion of soil particles inside the mixture. Hence, 8 % of SSA was chosen as the optimum value that was added to the laterite soil for micro-structural studies. Based on the SEM and EDAX results the new formed gel-like cementitious compounds of sodium aluminosilicate hydrate (N–A–S–H) were believed to be the main cause of strength development. The XRD results also revealed a general increase in the lateritic soil mineral peaks.

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APPENDIX

Table 1: Descriptive analysis (Water test)

		Temp (0C)	pH	Conductivity (μS/cm)	TDS (mg/L)	TSS (mg/L)	Alkanity (mg/L)	Salinity (mg/L)
N	Valid	6	6	6	6	6	6	6
	Missing	1	1	1	1	1	1	1
Mean		26.7833	6.3667	144.6667	94.0000	91.8333	53.0000	.0570
Std. Deviation		.11690	.05164	.51640	1.09545	.75277	.63246	.00063
Variance		.014	.003	.267	1.200	.567	.400	.000
Skewness		-.668	-.968	-.968	-1.369	.313	.000	.000
Std. Error of Skewness		.845	.845	.845	.845	.845	.845	.845
Kurtosis		-.446	-1.875	-1.875	2.500	-.104	2.500	2.500
Std. Error of Kurtosis		1.741	1.741	1.741	1.741	1.741	1.741	1.741
Range		.30	.10	1.00	3.00	2.00	2.00	.00
Minimum		26.60	6.30	144.00	92.00	91.00	52.00	.06
Maximum		26.90	6.40	145.00	95.00	93.00	54.00	.06

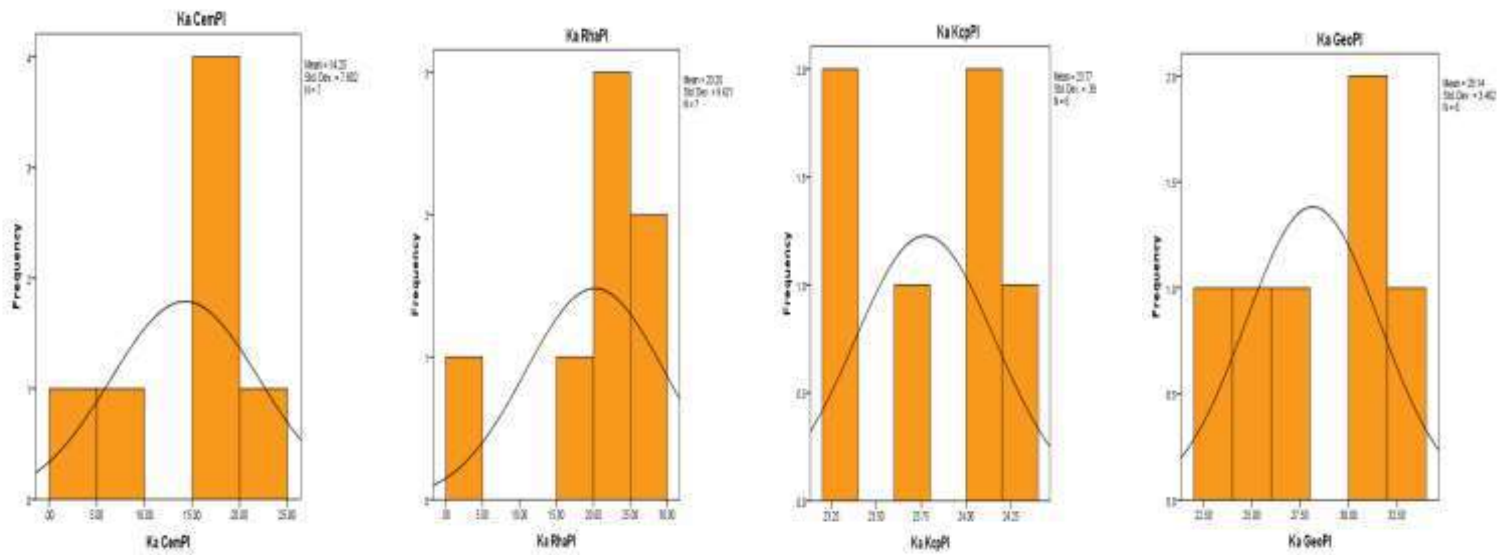

Figure 1: Histogram plot for cement, RHA, KCP and geopolymer stabilized soil.

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Table 5: Correlation analysis for Atterberg test (1- tailed significant)

Correlations

		percent	Ka CemPI	Sa CemPI	Da CemPI	Ka RhaPI	Sa RhaPI	Da RhaPI	Ka KcpPI	Sa KcpPI	Da KcpPI	Ka GeoPI	Sa GeoPI	Da GeoPI
Pearson Correlation	percent	1.000	-.714	-.416	-.729	.774	.962	.733	.859	-.788	.569	.845	.871	.795
	Ka CemPI	-.714	1.000	.866	.987	-.367	-.507	-.191	-.356	.710	-.880	-.696	-.712	-.533
	Sa CemPI	-.416	.866	1.000	.898	.117	-.173	.279	-.087	.730	-.643	-.485	-.618	-.123
	Da CemPI	-.729	.987	.898	1.000	-.320	-.519	-.151	-.361	.785	-.835	-.742	-.784	-.530
	Ka RhaPI	.774	-.367	.117	-.320	1.000	.845	.954	.723	-.221	.505	.532	.404	.886
	Sa RhaPI	.962	-.507	-.173	-.519	.845	1.000	.851	.942	-.672	.397	.732	.762	.775
	Da RhaPI	.733	-.191	.279	-.151	.954	.851	1.000	.786	-.207	.255	.517	.393	.783
	Ka KcpPI	.859	-.356	-.087	-.361	.723	.942	.786	1.000	-.641	.180	.540	.648	.531
	Sa KcpPI	-.788	.710	.730	.785	-.221	-.672	-.207	-.641	1.000	-.356	-.766	-.945	-.357
	Da KcpPI	.569	-.880	-.643	-.835	.505	.397	.255	.180	-.356	1.000	.502	.422	.659
	Ka GeoPI	.845	-.696	-.485	-.742	.532	.732	.517	.540	-.766	.502	1.000	.929	.749
	Sa GeoPI	.871	-.712	-.618	-.784	.404	.762	.393	.648	-.945	.422	.929	1.000	.591
	Da GeoPI	.795	-.533	-.123	-.530	.886	.775	.783	.531	-.357	.659	.749	.591	1.000
Sig. (1-tailed)	percent		.056	.206	.050	.036	.001	.049	.014	.031	.119	.017	.012	.029
	Ka CemPI	.056		.013	.000	.237	.152	.359	.244	.057	.010	.062	.056	.138
	Sa CemPI	.206	.013		.008	.412	.371	.296	.435	.050	.084	.165	.096	.408
	Da CemPI	.050	.000	.008		.268	.146	.387	.241	.032	.019	.046	.032	.139
	Ka RhaPI	.036	.237	.412	.268		.017	.002	.052	.337	.153	.139	.213	.009
	Sa RhaPI	.001	.152	.371	.146	.017		.016	.002	.072	.218	.049	.039	.035
	Da RhaPI	.049	.359	.296	.387	.002	.016		.032	.347	.313	.147	.220	.033
	Ka KcpPI	.014	.244	.435	.241	.052	.002	.032		.085	.367	.135	.082	.139
	Sa KcpPI	.031	.057	.050	.032	.337	.072	.347	.085		.245	.038	.002	.243
	Da KcpPI	.119	.010	.084	.019	.153	.218	.313	.367	.245		.155	.202	.077
	Ka GeoPI	.017	.062	.165	.046	.139	.049	.147	.135	.038	.155		.004	.043
	Sa GeoPI	.012	.056	.096	.032	.213	.039	.220	.082	.002	.202	.004		.108
	Da GeoPI	.029	.138	.408	.139	.009	.035	.033	.139	.243	.077	.043	.108	
N	percent	6	6	6	6	6	6	6	6	6	6	6	6	6
	Ka CemPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Sa CemPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Da CemPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Ka RhaPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Sa RhaPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Da RhaPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Ka KcpPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Sa KcpPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Da KcpPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Ka GeoPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Sa GeoPI	6	6	6	6	6	6	6	6	6	6	6	6	6
	Da GeoPI	6	6	6	6	6	6	6	6	6	6	6	6	6

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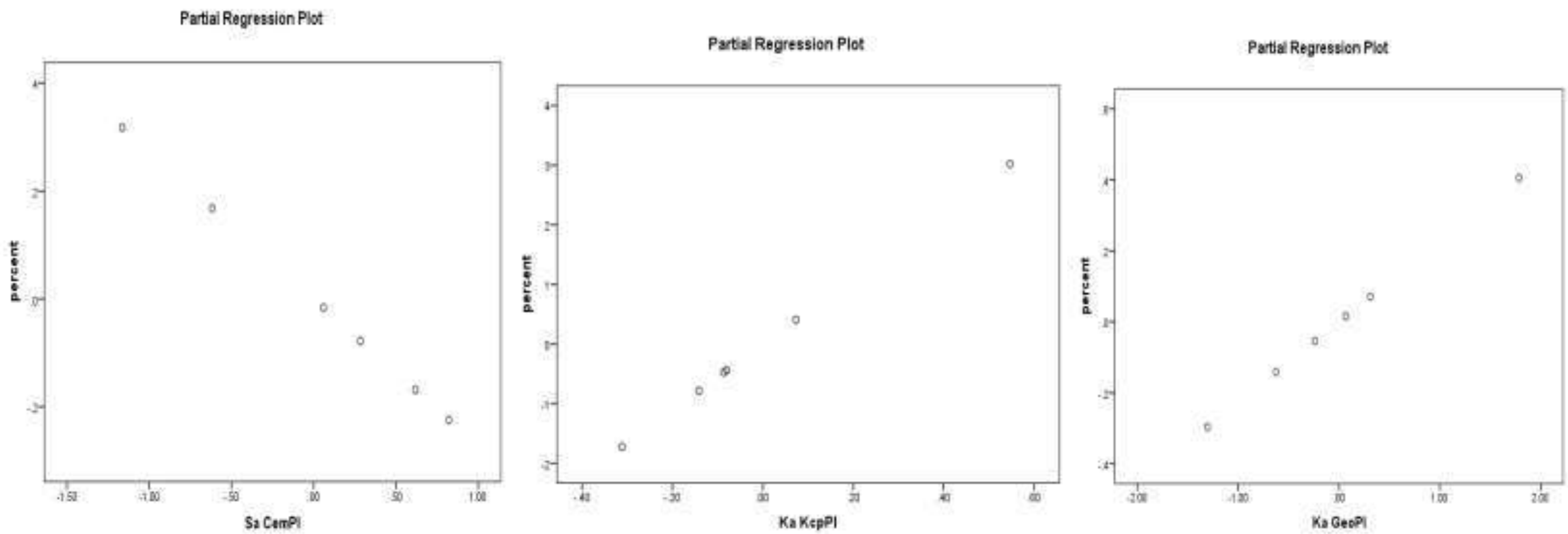

Figure 4: Correlation/ Regression Scatter plot from Atterbergtest results for cement, KCP and geopolymer for stabilized.

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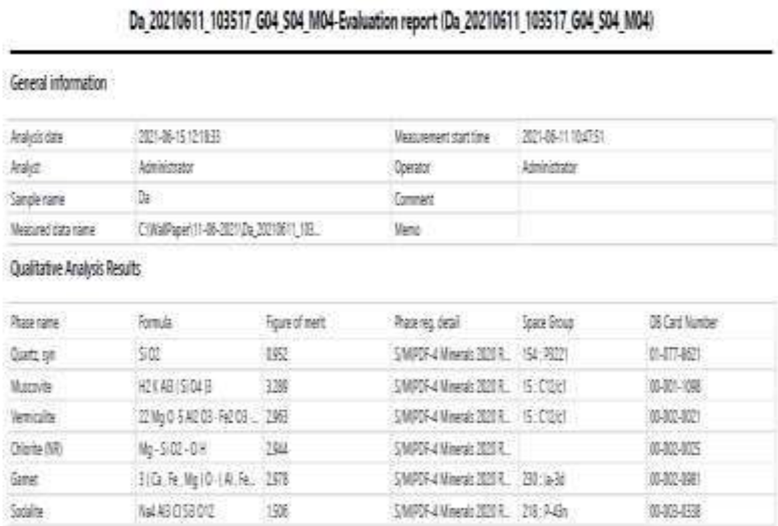


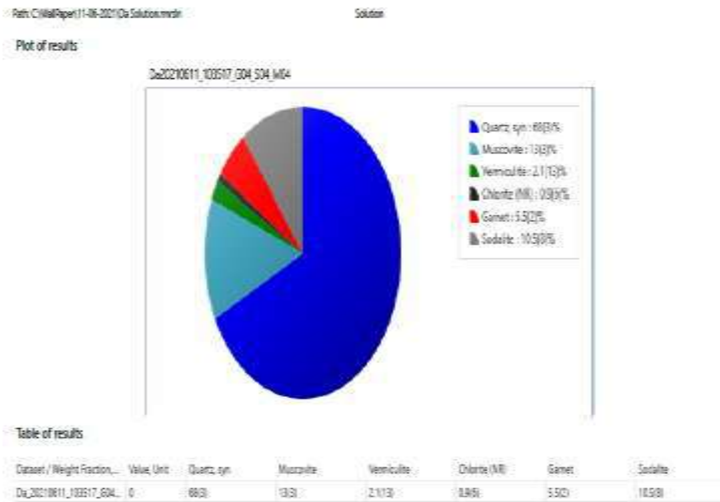
Da_20210611_103517_G04_S04_M04-Evaluation report (Da_20210611_103517_G04_S04_M04)

General information

Analysis date	2021-06-15 12:18:33	Measurement start time	2021-06-11 10:47:51
Analyst	Administrator	Operator	Administrator
Sample name	Da	Comment	
Measured data name	C:\WallPaper\11-06-2021\Da_20210611_103...	Memo	

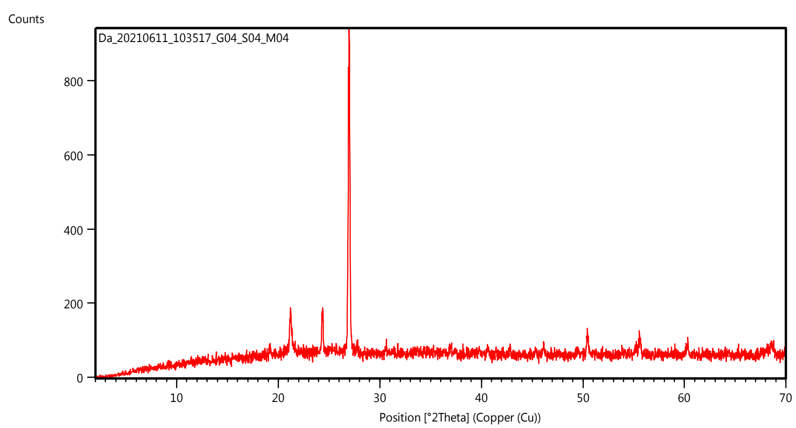
Qualitative Analysis Results

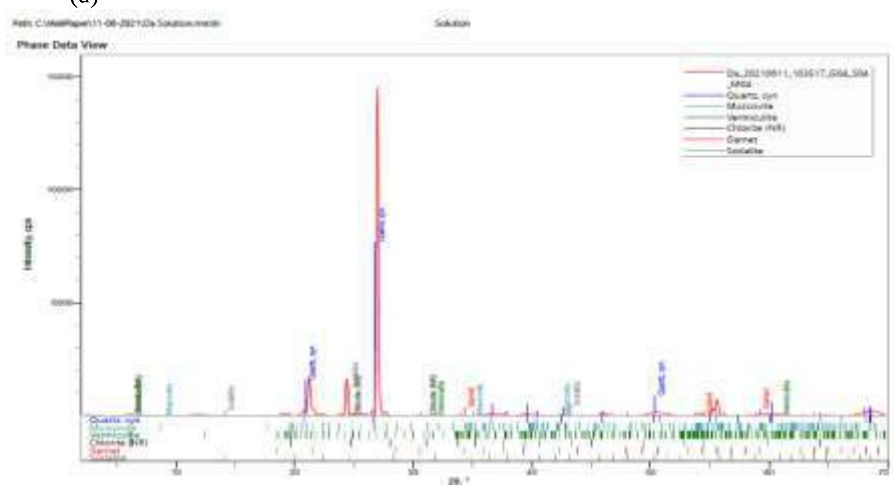
Phase name	Formula	Figure of merit	Phase reg. detail	Space Group	DB Card Number
Quartz, syn	Si O2	0.952	S/MPDF-4 Minerals 2020 R...	154 : P3221	01-077-8621
Muscovite	H2 K Al3 (Si O4)3	3.289	S/MPDF-4 Minerals 2020 R...	15 : C12/c1	00-001-1098
Vermiculite	22 Mg O · 5 Al2 O3 · Fe2 O3 ...	2.963	S/MPDF-4 Minerals 2020 R...	15 : C12/c1	00-002-0021
Chlorite (NR)	Mg - Si O2 - O H	2.944	S/MPDF-4 Minerals 2020 R...		00-002-0025
Garnet	3 (Ca , Fe , Mg) O · (Al , Fe...	2.978	S/MPDF-4 Minerals 2020 R...	230 : Ia-3d	00-002-0981
Sodalite	Na4 Al3 Cl Si3 O12	1.506	S/MPDF-4 Minerals 2020 R...	218 : P-43n	00-003-0338



Dataset / Weight Fraction,...	Value, Unit	Quartz, syn	Muscovite	Vermiculite	Chlorite (NR)	Garnet	Sodalite
Da_20210611_103517_G04...	0	68(3)	13(3)	2.1(13)	0.9(5)	5.5(2)	10.5(8)

(a)





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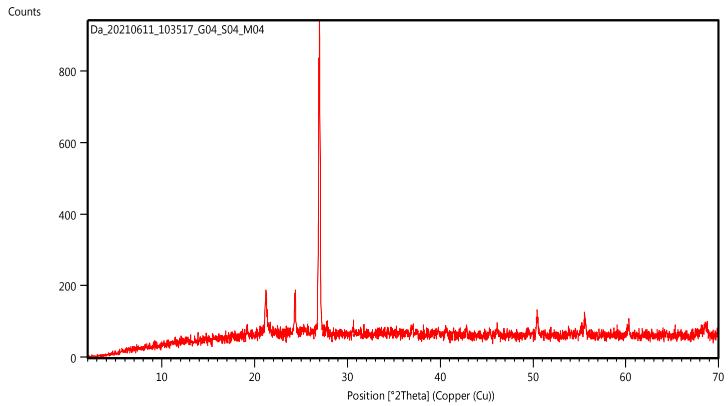
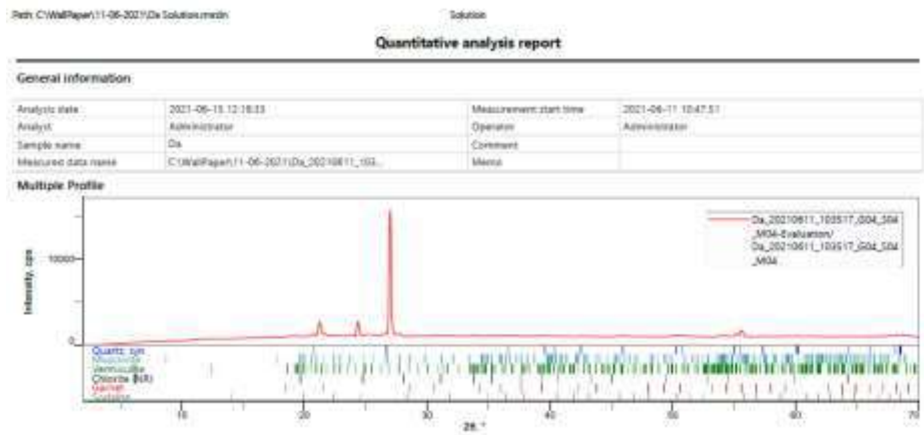
(b)





(c)

Figure 5: XRD analysis outcome on geopolymer lateritic soils.

Sample Name	DA	[redacted]	
Supplier	CLIENT		
Operator			
Date	6/11/2021 11:05		
GPS			
Testing time	15s		
Volt	45kV		
Curr	50uA		
Mode	Mineral Mode		
Specification			
Element	Content	Detection limit	Error
Al2O3(%)	24.2641	0.0000	0.5581
SiO2(%)	71.4911	0.0000	0.5350
K2O(%)	0.7214	0.0000	0.0776
TiO2(%)	0.2449	0.0000	0.0132
MnO(%)	0.0142	0.0000	0.0012
Fe2O3(%)	3.2110	0.0000	0.0244
Nb2O5(%)	0.0103	0.0000	0.0001
Ag2O(%)	0.0024	0.0000	0.0001
CdO(%)	0.0215	0.0000	0.0010
Sb2O5(%)	0.0189	0.0000	0.0010
PbO(%)	0.0003	0.0000	0.0000

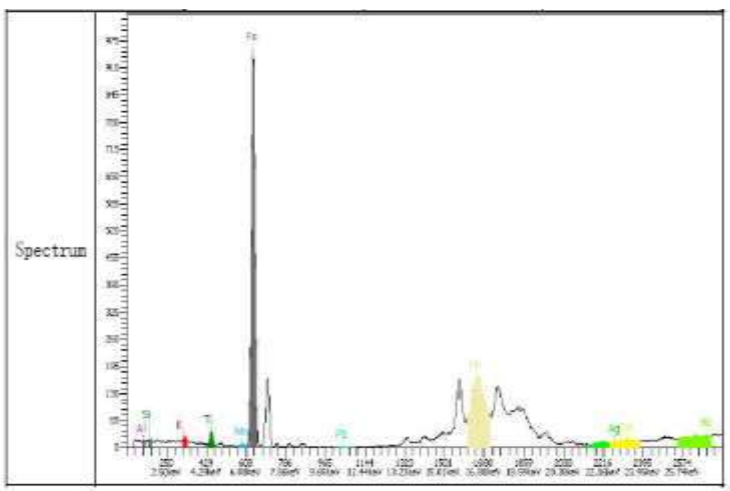


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Figure6: XRF analysis outcome on geopolymer lateritic soils.

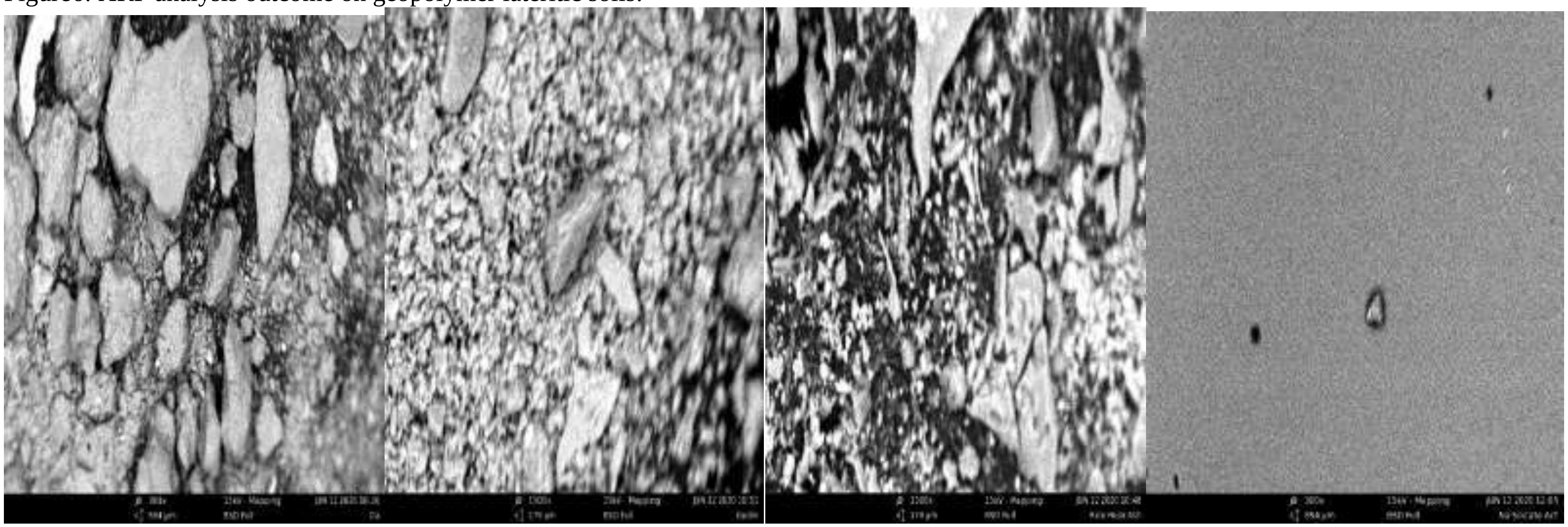

Fig. Figure 7: SEM for laterite, Kaolin, rice husk ash and Sodium silicate activator.

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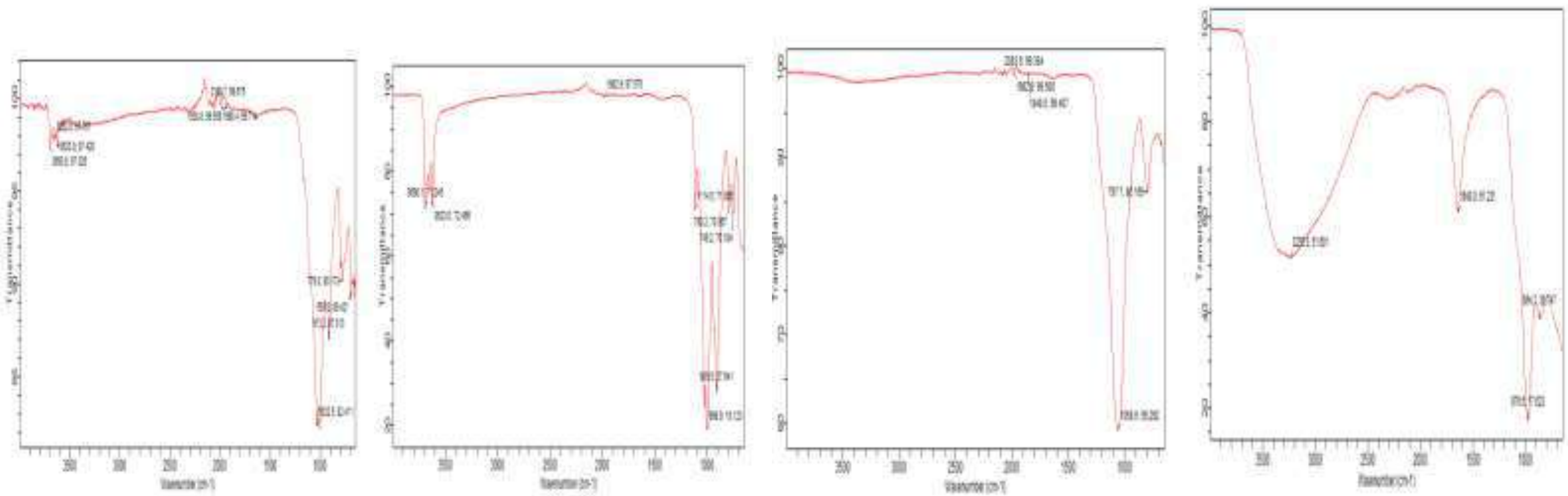

Figure 8: ***FTIR*** **Spectographfor laterite, kaolin,Rice Husk ash and Sodium silicate.**