Experimental Investigation of Direct Absorbing Characteristics of Therminol®55-Carbon Nano Tubes(nHTF) Using Solar Parabolic Trough Collector

N. S. Arunkumar, Bala Aravinthan. S, B. Giritharan, G. I. Kabbil,
Saranathan college of engineering
Tiruchirapalli 620012

Ms. A. Mercy Vasan
Asst professor,
Saranathan College of Engineering

***Abstract*:- This paper depicts the measurement of temperature absorbing characteristics of Therminol®55-Carbon Nano Tubes which is a nano heat transfer fluid (nHTF) in conjunction with concentrating solar parabolic trough collector. The experiment is conducted under the ambient outdoor conditions and solar radiation condition. The Volumetric Proportion of Carbon Nano Tubes is 0.025 vol% in 100 ml of Therminol®55. Two kinds of absorber tube is used for sealing 67 ml of nHTF ,one is copper tube of Diameter 10mm and another one is same copper tube enclosed in the evacuated tube whose vacuum pressure is 10^{-3}mbar.A highest temperature of 72.4°c was delivered by the solar collector using 0.025% concentration Carbon Nano tubes in the copper tube. This was 21.1°c higher than that obtained in the pure Therminol®55 (51.3 °c). Under the same condition of by using evacuated tube over the copper tube a highest temperature of 85.3 °c was obtained which is 20.1 °c greater than the pure Therminol®55 (65.2 °c). By comparing the two cases the temperature rise of 12.9 °c is obtained in the evacuated tube, therefore directly absorbing nHTF along with evacuated tube developed in this study are predicted to be strong candidate than the conventional absorber tubes due to its higher temperature absorbing and concentrating characteristics.**

Keywords : Solar,Parabolic trough, Therminol®55-Carbon Nanotubes(nHFT), Copper tube, Evacuator tube

INTRODUCTION:

Thermal properties of nHTFs are of specific enthusiasm because of their potential use as specifically retaining working liquid in Solar collector. Dispersion of nanoparticles (NPs) in conventional heat transfer liquids has been appeared to enhance their thermal properties, for instance, references (Choi and Eastman, 1995; Chandrasekar et al., 2010; Esfe et al., 2015). Chandrasekar et al. (2010) tentatively estimated thermal conductivity of Al2O3-water nHTF, for NP fixation changing from 0.33 vol% to 5 vol%, to be higher than that of water. Sani et al. (2011) revealed optical characterisation of nHTF including single-divider carbon nano horns and ethylene glycol. Hordy et al. (2014) examined steadiness of plasma functionalized multi-walled carbon nanotubes suspension in ethylene glycol and propylene glycol at 170 _C for 8 months. Agglomeration was found to happen in non-polar Therminol VP-1 heat transfer liquid. Gupta et al. (2015) detailed a 39.6% ascend in immediate proficiency for a level plate Solar collector when specifically retaining Al2O3-water nHTF nanofluid with 20 nm Al2O3 nanoparticles 0.005 vol% was utilized. A reasonable ideal volume group of 0.005% was seen because of an accompanying increment in thermal misfortune as the sunoriented retention expanded. Taylor and Phelan (2011) portrayed displaying and exploratory techniques to decide the optical properties of nHTFs. Khullar et al. (2012) hypothetically anticipated a 5–10% higher productivity for an explanatory concentrator utilizing nHTF comprising of round aluminum NPs suspended in Therminol VP-1 than a traditional explanatory sun powered authority. Anoop and Sadr (2013) revealed an ascent in refractive file by <1% with an increment in nanoparticle loadings in SiO2 - water nHTF. Said et al. (2014, 2015) researched the impact of size and grouping of TiO2 NPs on optical properties of nHTF. The span of NPs (TiO2 and Al2O3) was found to nominally affect optical properties of water based nHTFs while the elimination coefficient expanded straightly with increment in volumetric focus. Additionally, it was found that TiO2 would do well to optical properties than Al2O3, yet it framed a less steady suspension in water than the later. Thermo-physical characterisation of Therminol_55 based nHTFs containing MgO NPs (Manikandan and Rajan, 2015) and CuO NPs (Naresh et al., 2012) have additionally been accounted for.

2. EXPERIMENTAL DETAILS

nHTF preparation Fig. 1 shows the methodology adopted for the preparation of Carbon Nano tubes(CNT)-Therminol_55 nHTF and its characterisation. Commercially available Carbon Nano tubes(CNT) nanoparticles with 98% purity which is having high thermal conductivity and elastic property. (surface area 1000 m2/g) were used to prepare nHTF. Surface morphology and microstructure of the nano particles was observed using a scanning electron microscope. Therminol-55 (Therminol_55) was used as the base. The amount of nanoparticles added to the base fluid to achieve a particular volumetric concentration (ϕ was calculated using Eq. (1).

$$\phi = \frac{W_{np/}\rho_{np}}{W_{np/}\rho_{np} + w_{bf} \,/\, \rho_{bf}}$$

where W_{np} is the mass of NPs; ρ_{np} is the density of NPs; W_{bf} is the mass of base fluid; ρ_{bf} is density of base fluid. Fig .1b Shows Mixture containing 0.025 g of CNT was first prepared and dispersed into 100ml of Therminol_55 using a magnetic stirrer for 45 min. Further to improve the stability of the nHTF sonication was done using an ultrasonic bath for 45 min as shown in the Fig 1c. This procedure was followed to prepare samples of nHTF containing volumetric concentration of CNT, 0.025 vol%. Fig. 1e shows sample of the nHTFs prepared with the fluid colour getting dark grey as the concentration of NPs increased.

Performance of nHTF in line-axis solar parabolic trough collector:

The directly absorbing nHTFs was tested under real life outdoor conditions using a concentrating solar parabolic trough collector system typically developed for this purpose during the experiment. The concentrator contains two flat line axis solar focusing copper receiver tubes and replacing the copper tubes by evacuated tube enclosed copper receiver tubes. Receiver tube details are provided in Table1 & Table2. The collector was held in true North-South direction (surface azimuth angle 0_) and manually tracked about this axis to follow the movement of sun along East-West axis. The evacuated receiver tubes consisted of an outer glass tube (external diameter 25 mm) surrounding an inner glass tube (internal diameter 10 mm). The annular space between the outer and inner tubes was evacuated to a low air pressure of 10_3 mbar to suppress the convective heat loss from the warmer nHTF flowing through the internal tube to the surroundings. The two receiver tubes were located parallel to each other. Procedure for nHTF preparation and is shown in Fig. 1a to Fig 1e with Fig. 1d showing the concentrator being tested outdoors and Fig. 1f an illuminated receiver tube containing nHTF. The receiver tubes were supported by an aluminium adjustable box frame and the receiver tubes assembly were tracked by a manual tracking. During testing the directly absorbing nHTF was filled and it is stagnant. Two calibrated k-type thermocouples (accuracy ± 0.5 _C) were deployed at the outlet of each receiver to measure nHTF temperatures and another two thermocouples are inserted in the copper receiver tubes and evacuated tube enclosed copper receiver tubes Fig .1g

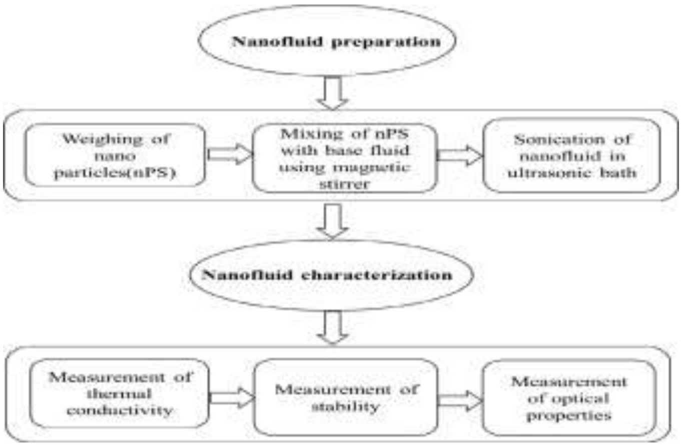

Fig1: Procedure for nHTF preparation and characterisation adopted.

Experimental setup and Preparation of Therminol®55-CNT nano heat transfer fluid

FIG 1a: PURE THERMINOL®55

FIG 1b: DISPERSION OF CNT USING MAGNETIC STIRRER

FIG 1c: nHTF IN ULTRASONIC BATH

FIG 1d: EXPERIMENTAL SETUP WITH TEMPERATURE INDICATOR

FIG 1e: TRANSFORMATION OF COLOUR FROM PALE YELLOW TO DARK GREY

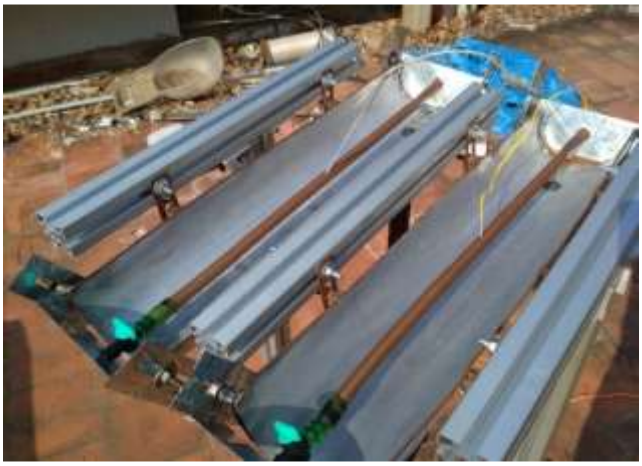

FIG 1f: FLUIDS ENCLOSED IN COPPER TUBE

FIG 1g: FLUIDS IN COPPER TUBE ENCLOSED IN EVACUATED TUBE

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Table 1: Temperature readings of the fluids using copper tubes

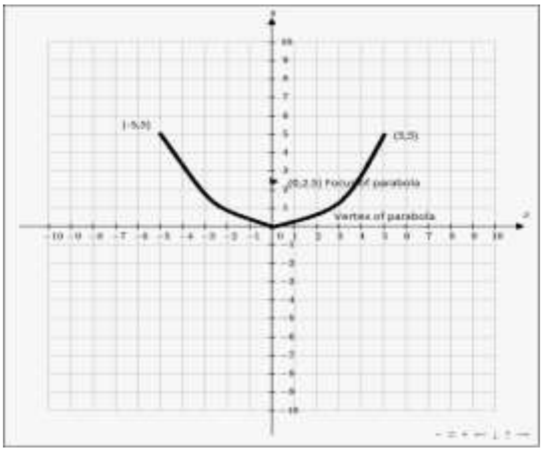
S.N0	TIME INTERVAL (15 MINUTES)	THERMINOL®55-CNT		THERMINOL®55 WITHOUT CNT	
		TROUGH TEMPERATURE T1 (°C)	FLUID TEMPERATURE T2 (°C)	TROUGH TEMPERATURE T3 (°C)	FLUID TEMPERATURE T4 (°C)
1	10:00	33.5	37.2	32.5	37.2
2	10:15	34.2	38.5	33.2	38.4
3	10:30	35.3	39.7	34.4	42.2
4	10:45	37.8	41.2	37.3	45.3
5	11:00	38.6	42.7	38.2	47.4
6	11:15	39.7	43.2	40.3	50.6
7	11:30	41.5	44.6	41.9	52.7
8	11:45	43.2	45.9	43.8	54.3
9	12:00	42.3	44.8	45.0	55.5
10	12:15	45.2	46.3	45.2	58.3
11	12:30	47.9	48.7	47.9	60.6
12	12:45	44.3	47.2	44.3	63.1
13	13:00	45.2	46.3	45.2	62.8
14	13:15	43.2	45.7	43.2	66.1
15	13:30	44.1	47.5	44.1	69.4
16	13:45	46.7	48.6	46.7	70.3
17	14:00	48.2	51.3	48.2	72.4
18	14:15	44.3	50.7	44.3	68.3
19	14:30	38.8	47.3	38.8	64.5
20	14:45	34.2	45.8	34.2	60.2
21	15:00	34.0	44.5	34.0	58.7

Table 2: Temperature readings of the fluids using copper tubes enclosed by evacuated tubes

S.N0	TIME INTERVAL (15 MINUTES)	THERMINOL®55-CNT		THERMINOL®55 WITHOUT CNT	
		TROUGH TEMPERATURE T1 (°C)	FLUID TEMPERATURE T2 (°C)	TROUGH TEMPERATURE T3 (°C)	FLUID TEMPERATURE T4 (°C)
1	10:00	33.5	37.2	34.3	37.2
2	10:15	33.5	38.5	35.0	39.2
3	10:30	36.1	40.3	35.4	42.4
4	10:45	43.0	43.4	40.7	45.2
5	11:00	41.5	45.3	40.	48.3
6	11:15	43.4	47.6	41.9	51.6
7	11:30	42.3	48.8	40.9	54.5
8	11:45	43.8	51.2	41.8	57.3
9	12:00	42.9	53.2	41.1	56.6
10	12:15	43.9	56.9	41.3	64.2
11	12:30	45.4	57.2	44.5	67.3
12	12:45	48.0	58.4	43.0	66.6
13	13:00	45.6	60.7	44.5	71.3
14	13:15	47.5	61.3	45.7	75.9
15	13:30	46.8	61.9	44.9	80.2
16	13:45	45.1	62.5	46.7	81.7
17	14:00	49.4	64.5	48.2	82.3
18	14:15	44.3	63.5	44.3	83.2
19	14:30	38.8	65.2	38.8	85.3
20	14:45	34.2	57.3	34.2	80.7
21	15:00	34.0	55.2	34.0	79.9

Calculations:

Calculation of focal length of the parabolic trough



The below values are obtained from **PARABOLA CALCULATOR V2.0**

Assume that the equation of the parabola is $y=ax^2+bx+c$.

Since the parabola passes through the point (0,0) then 0=c

Since the parabola passes through the point (−5,5) then 5=25a−5b+c.

Since the parabola passes through the point (5,5), then 5=25a+5b+c

Thus, we have obtained the following system:

25a−5b+c=5

25a+5b+c=5

Solving the system of linear equations we get that a=15 b=0, c=0

Thus, the equation of the parabola is $y=15x^2$

Equation of the parabola: $y=15x^2$

No intercept form.

Vertex: (0,0)

Focus: (0,5/4)=(0,1.25).

Axis of symmetry: x=0

Results & Discussions:

Thermal conductivity:

All nanotubes are relied upon to be great thermal conductors along the tube, showing a property known as "ballistic conduction", however great separators parallel to the tube hub. Estimations demonstrate that an individual SWNT has a room-temperature thermal conductivity along its pivot of around 3500 W·m−1·K−1; contrast this with copper, a metal surely understood for its great thermal conductivity, which transmits 385 W·m−1·K−1. An individual SWNT has a room-temperature thermal conductivity over its pivot (in the spiral bearing) of around 1.52 W·m−1·K−1,], which is about as thermally conductive as soil. Perceptible gatherings of nanotubes, for example, movies or strands have come to up to 1500 W·m−1·K−1 so far. The temperature soundness of carbon nanotubes is evaluated to be up to 2800 °C in vacuum and around 750 °C in air .The structure of Carbon nanotube is shown in the below fig.2

Absorption Co-efficient:

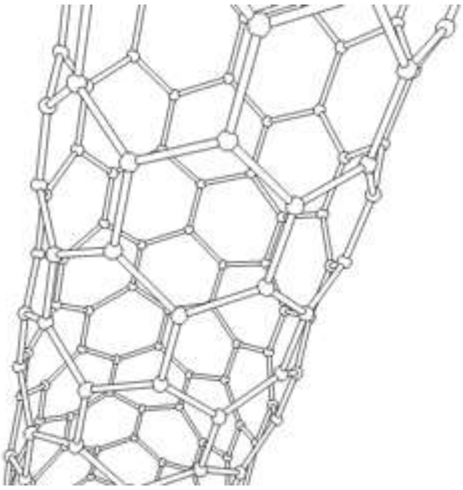


Fig2: Single walled zig-zag carbon nanotubes

Based on the experimental observation the thermal conductivity of Therminol®55-Carbon Nano Tubes increases with increase in concentration of CNT (250ppm)

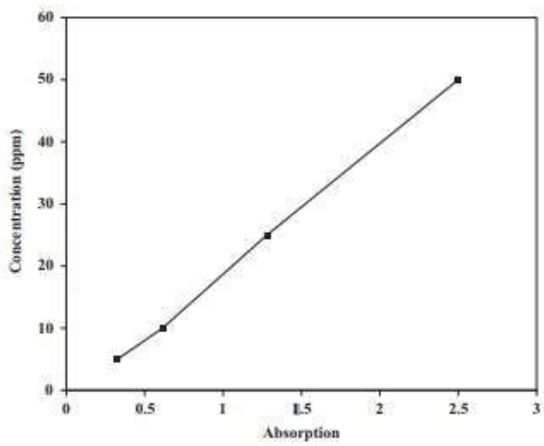
Thermal conductivity of the samples increases with increase in temperature; even though their increase trends are different. The reason is that Brownian motion of NPs in the fluid which increases chaos in the fluid. The experimentally determined spectral transmission confirmed that CNT has an important role in raising the optical properties of the fluid, due to increase of the light extinction level even at low volume fractions. The results show that the presence of 250 ppm CNT increases the extinction coefficient of pure water by about 4.8 cm^{-1}.

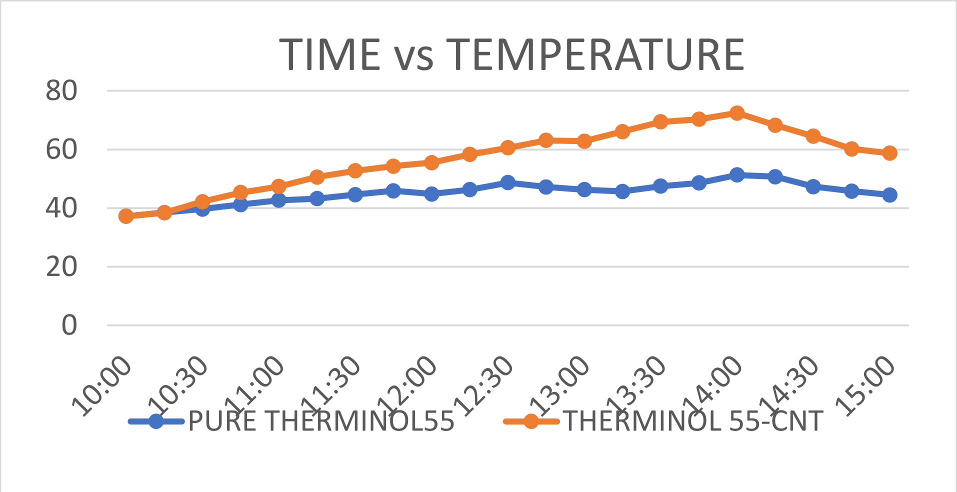
By adding 250 ppm we have observed that there is a temperature rise up to 85^0c according to the atmospheric outdoor condition. The extinction co-efficient also increases respectively with respect to amount of ppm of CNT in Therminol®55.Concentration vs absorption is shown in fig.3

and increase in temperature of outdoor conditions. By concentrating the solar radiation in line focus using parabolic trough collector it affects the thermal conductivity considerably by increasing the temperature of the fluid. The evacuated tube which encloses the copper tube also concentrate more radiation of light increases thermal conductivity.

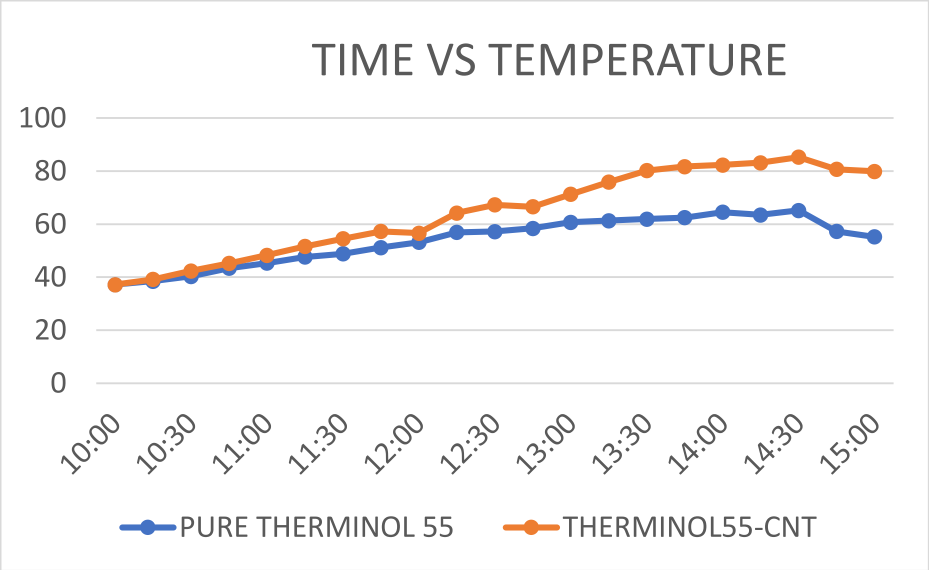
Time vs Temperature Graph:

The graph describes the Time(X-axis) Vs Temperature(Y-axis) curve. It shows that with respect to time and increase in outdoor temperature there is a considerable increase in the fluid temperature due to the concentrating factors. Three graphs are shown below:(Graph.1) shows the temperature distribution of fluid enclosed in copper tube, (Graph2) shows the temperature distribution of the Therminol®55-Carbon Nano Tubes fluid contained in copper tube which is enclosed by a evacuated tube. (Graph3) shows the comparison of both.

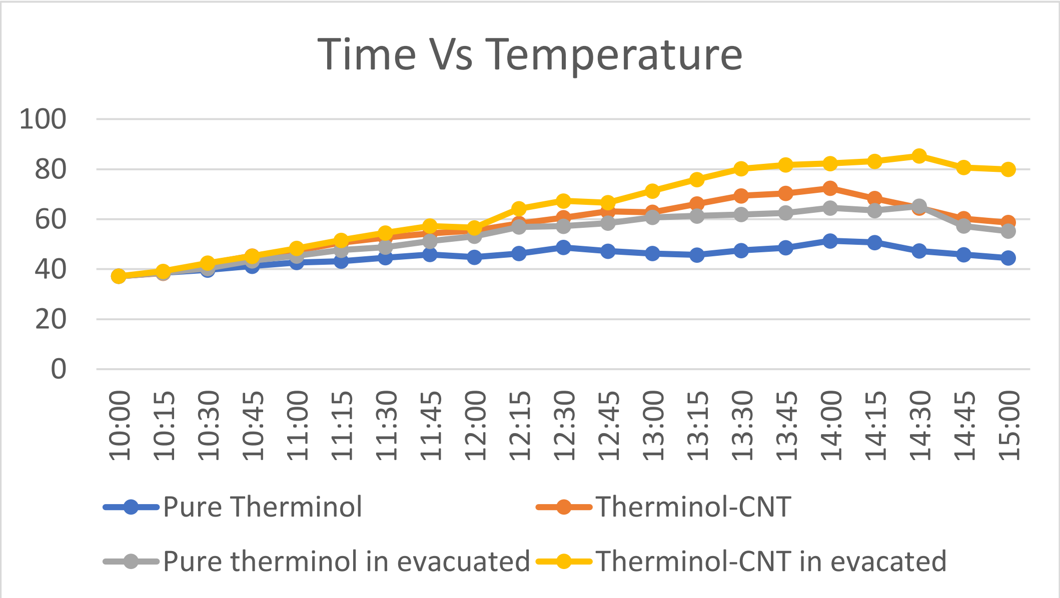




Graph1: Fluid in Copper tube



Graph2: Fluid in Evacuated tube enclosed Copper tube



Graph3: Comparison of the above two graphs

CONCLUSION:

The above discussion shows that the thermal conductivity and absorption co-efficient of the Therminol®55-nHTF fluid increased considerably with respect to the increase in temperature of outdoor conditions. The concentration of solar radiation in line-focus to the tube with the help of solar parabolic trough collector also increases thermal conductivity. By comparing the temperature values obtained from the above two setups (1) using pure Therminol®55 in copper tube the maximum temperature value noted is 51.3ºC, (2) using Therminol®55-Carbon Nano Tubes in copper tube the maximum temperature value noted is 72.4ºC, (3) using pure Therminol®55 in evacuated tube enclosed copper tube the maximum temperature value noted is 65.2ºC, (4) using Therminol®55-Carbon Nano Tubes in evacuated tube enclosed copper tube the maximum temperature value noted is 85.3ºC. Therminol®55-Carbon Nano Tubes in evacuated tube enclosed copper tube has attained the maximum temperature which can be used for some small heating applications. Utilising the heat, we can use it for water heating applications in water heaters.

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d Department of Marine Science and Technology, School of Earth and Mineral Science, The Federal University of Technology, P.M.B. 704 Akure, Nigeria e Department of Civil and Environmental Engineering, Hanyang University, 222 Wangsimni-Ro, Seoul 04763, Republic of Korea

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