SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943


# The Impact of Density and Porosity on Thermal Properties of Kernelrazzo Concrete Floor Finish

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**ARTICLE INFO**

***Article history:***
Received 16 November 2022
Received in revised form 8 December 2022
Accepted 30 December 2022
Available online 21 January 2023

***Keywords:***
Kernelrazzo; Density; Porosity; Thermal conductivity; Thermal diffusivity; Specific heat capacity

**ABSTRACT**

Understanding the impact of density and porosity on the thermal characteristics of kernelrazzo concrete floor finish was the study's main goal. Kernelrazzo is a combination of palm kernel shell, marble chippings in place of terrazzo, quarry dust, cement, palm oil fuel ash and water. In this study, it was determined which factors normally have the biggest influence on the thermal development of kernelrazzo concrete by conducting a scan of the literature and specifications. In this study, experiments in the laboratory were carried out at USM's HBP Concrete Lab. The components were mechanically combined in a concrete mixer with the calculated water using the Department of Environment (DoE) method. Concrete mix design for M20 grade is included in the scope of laboratory investigations. Ordinary Portland Cement (OPC), palm oil fuel ash (POFA) was used as an added pozzolana element, and quarry dust, aggregates made from palm kernel shell (PKS), and marble chippings were utilized to create the mixture. By examining kernelrazzo concrete cube samples after proper curing, the study involved estimating density, specific heat, thermal diffusivity, and thermal conductivity. Density is important to control the material's thermal characteristics of kernelrazzo concrete. Lower-density kernelrazzo concrete is a sign of more porosity. In lower-density kernelrazzo concrete, specific heat capacity, thermal diffusivity, and thermal conductivity are all decreased. There is strong relationship between thermal properties, temperature, density, water, and porosity.

## 1. Introduction

The use of palm kernel shell as lightweight concrete (PKSC) in building construction and housing development has just started gaining awareness greatly throughout the world and the by-product generated from the oil palm industry facility is undoubtedly substantial, can be used for commercial purposes, and benefits the environment [1]. Due to the tightening financial situation, alternative materials that are relatively less expensive and perform nearly the same goals as the traditional ones are becoming more and more popular in the building industry. A building is a mechanism that is

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https://doi.org/10.37934/araset.29.2.291303

designed and built for human habitation and safety. Schools, hospitals, mosques, churches, industrial and commercial buildings, public buildings, domes, silos, housing estates, etc. are examples of buildings [2]. Infrastructure facilities include accessibility and proximity to common locations, the layout of public areas, the variety of land uses, the availability of recreational opportunities, and neighborhood maintenance standards [3-6]. Construction protection from environmental deterioration caused by air movement, radiation, chemical and biological attack, moisture, temperature, or natural calamities like fire or flood, must be one of a building's primary purposes [7]. The employment of complex design, newly introduce construction materials such as kernelrazzo concrete to reduce the cost of flooring, and contemporary construction technology has undergone a great and progressive revolution in modern building [8]. The quality and rich history of a house's function in the built environment is to have an impact on its social, commercial, and cultural attraction. In addition, it needs to include interior occupancy criteria and basic comfort parameters. Analyzing the connection between the worth and excellence of the developed environment in relation to human health, society, the economy, and the environment [9].

Kernelrazzo concrete floor finish is a composite material comprising of marble chippings, ordinary Portland cement, quarry dust, palm oil fuel ash (POFA), water, and palm kernel shell. It is like two partial substitutions of palm oil fuel ash (POFA) fraction for cement and PKS for marble chippings. Kernelrazzo concrete floor finish is another new material, and it is produced by mixing palm kernel shell with quarry dust, ordinary Portland cement, palm oil fuel ash (POFA) and marble chippings. Kernelrazzo is a variant of terrazzo floor finish in which marble chippings have been partially or wholly replaced by a palm kernel shell [10-14]. However, it may more appropriately be termed kernelrazzo since it is a palm kernel shell that is utilized in producing the floor finish. The replacement of marble chippings in terrazzo by palm kernel shells either wholly or partially is termed kernelrazzo. The free and compressed bulk densities of palm kernel shells range from around 500 to 550 kg/rn$^3$ and 590 to 620 kg/m$^3$, respectively, because of their higher porosity than conventional aggregates. These density arrays demonstrate that palm kernel shells are almost 60% less weight than usual coarse materials [15-18]. The densities of the shell fall within the range of the majority of commonly used lightweight aggregates [15-18]. The bulk densities of palm kernel shells while they are loose and compacted range from 500 to 600 kg/m$^3$ and 595 to 740 kg/m$^3$, correspondingly. The density of concrete produced of palm kernel shell (PKS) typically ranges between 1600 and 1900 kg/m$^3$ due to the lower density of PKS [19,20]. The specific gravity of the shell's varies from 1.14 to 1.37, and their density falls between the bulk of typical lightweight materials. As more oil palm shell is used, the strength of the concrete gradually deteriorates. The density of concrete gradually dropped as the amount of substitute oil palm shell rose in the researches by Belmokaddem *et al.,* [21] and Ahmad and Yahya [22] and a conclusion was reached that palm kernel shell can be used as a replacement hard material in lightweight concrete by using 10% palm kernel shell in both water-cement ratios because of the low strength requirements, most of them cannot be used for concrete. Previous research by several authors have examined the characteristics of PKS as a lightweight material to create lightweight material concrete [23-26]. The porosity of palm kernel shell (PKS), a porous aggregate, is about 37% [27].

Porosity was discovered to be one of the factors affecting the thermal conductivity of lightweight concrete [28-35]. The quantity of heat that, under steady-state conditions, is transported through a unit thickness in a direction perpendicular to a unit-area surface because of a unit temperature gradient is known as thermal conductivity. The capacity of concrete to conduct heat, expressed in Watts per metre per degree (symbol: W/mK), is known as thermal conductivity. The material's thermal conductivity is a characteristic that is independent of a material's dimensions but is affected by temperature, density, and moisture content. The composition of the concrete, which in this case consisted of granite dust and palm kernel shells in different mix ratios, as well as its density and moisture content all affect thermal conductivity.

A naturally available stone such as marble chippings, quarry dust, and new substitute like palm oil fuel ash (POFA) as a partial substitute for cement and PKS utilized as a flooring material. Marble can be positioned over the ready concrete basis and come in the shape of flat slabs. Marble slab is to be smoothened with abrasive stone, whereas granite does not need any glossing. Marble's demand as a flooring material has increased because of its hardness, durability, and attractive appearance.

Terrazzo is a composite material that can be prefabricated or poured in place and is applied on floors and walls. It is composed of marble, quartz, granite, glass, or other relevant chips that have been poured with a cementitious, chemical, or hybrid binder. Terrazzo is completed in one of several ways to provide a surface with a consistent texture, including curing, grinding, and polishing. Traditional terrazzo flooring is made of marble or granite chips embedded in concrete and brightened to a smooth surface to provide a decorative design of tiny, spaced-out coloured silver [36].

One of the first recycled products was terrazzo, which comes from the Italian term for terraces. The first faux-stone floors were made in Italy during the fifteenth century by Venetian craftsmen using unused marble refuse and cement adhesive. Since that time, terrazzo has developed with a wide variety of styles and options as well as the highest level of toughness and ease of upkeep, generally lasting the lifetime of the structure. All-natural, non-toxic materials that are beneficial to the environment are used to create terrazzo. It is a perfect combination of natural stone chips, glasses, cement, and water without containing any resin glue component. The standard size of terrazzo is 2400 x 1800 x 20mm and 2400 x 1600 x 20mm. It is a homogenous material with 18mm and 20mm thickness, available to be polished even the surface edges. Terrazzo product has been tested under the European standard with SGS test report to assure the quality product is delivered. The main objective is to promote kernelrazzo as a sustainable material to the public for its durability, flexibility, and timeless design. Terrazzo Malaysia specializes in providing extra-large terrazzo slabs to maximize the possibility of the ultimate design. Kernelrazzo from this report is made with natural ingredients that are environmentally friendly. It is a perfect combination of natural palm kernel shells, marble chippings, stone dusts, cement, and water.

## 2. Materials and Methodology

The research tools and technique used to evaluate how well kernelrazzo concrete floors function in relation to the performance of palm kernel shell, marble chippings, palm oil fuel ash, quarry dust, cement, and water are described on thermal characteristics of kernelrazzo concrete. It includes the laboratory experimentation schedule and the analytical methods applied in this investigation. the materials used, the spot where the collection was made, the methods, and the various characteristics of these materials as determined by laboratory testing on density, porosity and thermal properties are described. This experimental work was done at the USM, HBP Concrete and Materials Laboratory. Analysis was done on the data produced by the laboratory experimentation.

The lightweight kernelrazzo concrete used in this study was made from ordinary Portland Cement (OPC), palm oil fuel ash (POFA), quarry dust, palm kernel shell (PKS), marble chippings, and water. This study's primary goals are to ascertain the thermal conductivity of kernelrazzo concrete to create the lightweight kernelrazzo concrete specimens for this study, only a constant cement-POFA binder and water-cement ratio of 0.5 will be employed for all batches. Ordinary Portland cement (OPC) Type 1, a cement that complies with the [37,38]. Cement increases the fastening characteristic of concrete [39]. The cement used for this study was produced by Tasek Corporation Berhard having a specific gravity of 3.15 g/cm$^3$. Blaine's specific surface area for this cement was 3510 cm$^2$/g. Palm oil fuel ash is one of the locally sources of agricultural and industrial waste to combine with cement to make high strength concrete. The ultrafine particles (1 m) enable a tighter packing of the concrete microstructures.

Palm oil fuel ash (POFA) is an agricultural waste carelessly thrown in landfills in Asia and West Africa and POFA was acquired from United Oil Palm Nebong, Malaysia [40]. The palm oil fuel ash had a specific gravity of 1.65. Palm oil fuel ash (POFA) can be categorised as a highly pozzolanic supplemental cementing ingredient. With ASTM C618 [41] due to the presence of cumulative mass of oxide components. It is a by-product from the silicon and ferrosilicon industry. The gaseous silicon dioxide ($SiO_2$) that escapes from the submerged-arc electric furnace undergoes oxidation and condensation to produce silica fume, which is made up of incredibly small spherical particles of amorphous silica [42]. Palm oil fuel ash can regenerate and reuse out of the plentiful waste agricultural materials. Palm oil fuel ash (POFA) has become necessary for pozzolana additive of cement in kernelrazzo concrete floor finish.

Quarry dust, a fine aggregate utilised as an inert filler to produce the study's samples, was purchased from a material merchant in Penang, Malaysia. A large percentage of particles define a fine aggregate. passing a No. 4 Sieve of 4.75 mm and mainly holden on 75 mm (No. 200 Sieve). Fine aggregate is subjected to sieve analysis in line with BS EN 12620 [43] to obtain its sizing, specific gravity, and water absorption measurements. The aggregate percentage holden on sieves, multiplied by 100, and the sieve's stated in the smoothness or fineness modulus has specified in ASTM C33 [44].

The marble chippings used were obtained from Ipoh Marble Industry, Ipoh, Malaysia, and the palm kernel shells used for the research work were gotten from Penang, Malaysia. The procedure followed the method prescribed by ASTM C796 [45]. The palm kernel shell after collection were stalked for 3 weeks and then followed the processes below before their used as partial replacement for marble chipping.

A water-cement ratio of 0.5 was found satisfactory to attain sufficient workability. Water used to make concrete clings to BS 3148 [46] standards. Concrete mixing can be done with water that is safe for drinking. It shouldn't be overly polluted with acids, salts, bases, or organic and inorganic elements. In this studies, regular drinking water from the HBP Laboratory was used during the period of this research.

### *2.1 Constituents of The kernelrazzo Concrete*

When creating the kernelrazzo concrete mixtures, several observations were made. These observations consist of the measured fresh density, the PKS, MC, and QD quantities necessary to reach the design density, as well as the actual water demand. The components of kernelrazzo concrete mixes are listed in Table 1 and include palm kernel shell, marble chippings, cement, quarry dust, actual water demand, base mix density, and measured fresh densities.

The kernelrazzo concrete samples utilized in this experimental study were made with tap water. Kernelrazzo concrete samples each measured 100 x 100 x 100 mm were made at six separate mix design series that have been designed and tested namely PPOF-1, PPOF-2, PPOF-3, PPOF-4, PPOF-5, and PPOF-6. The components were mechanically combined in a concrete mixer with the calculated water using the DoE method. Before the addition of the cement and POFA as the binding agent, the palm kernel shell, marble chips, and quarry dust were well combined. Water was then added after carefully combining the entire mixture.

Water is gradually added to the dry ingredients during the manufacturing process. All kernelrazzo concrete samples were made in the laboratory. The mixtures within the same samples were identified by the amount of palm oil fuel ash, cement, marble chippings, quarry dust, PKS and water to be used. Using the Department of Environment (DoE) approach, the mixes in samples PPOF-1 through PPOF-6 were created to achieve a goal compressive strength of 30 MPa at 28 days. The cement was mixed with POFA, PKS, and marble chippings were mixed in the mixer for a few minutes. Then water was added gradually until the desired compactions were obtained. When a uniform mix was attained, mixing was thought to be finished. To ensure simple demoulding and a smooth surface finish, mould oil was applied to the interior of the plastic mould in each instance prior to casting.

The wet material was cast immediately after mixing, poured into the moulds using a hand trowel, and compacted on a vibratory table. The cube samples were kept in a space free from vibration and away from heat sources like the sun. Kernelrazzo concrete lightweight was measured at ambient temperature and found according to the ASTM D5334 [47] and ISO 22007 [48], using Hot Disk TPS2500S at 28 days curing. Three identical samples of the kernelrazzo concrete were cut 0.1 mm x 10 mm square slab testing between and within the range of -235 °C to 1000 °C. All samples were professionally cleaned and smoothed with sandpaper to prevent damage and scratching of the sensitive sensor employed. This was carried out to make sure that the Sensor and the cleaned smooth samples. Further details of the mixing constituent proportion are shown in Table 1.

**Table 1**
Mix constituent proportions of kernelrazzo concrete mixes (kg)

| Sample | Binding agent (kg) | | Coarse aggregate (kg) | | Quarry Dust (kg) | Water (kg) |
|---|---|---|---|---|---|---|
| | POFA | Cement | PKS | MC | | |
| PPOF-1 | 0.00 | 6.048 | 3.36 | 13.43 | 8.27 | 3.02 |
| PPOF-2 | 0.30 | 5.75 | 3.36 | 13.43 | 8.27 | 3.02 |
| PPOF-3 | 0.60 | 5.44 | 3.36 | 13.43 | 8.27 | 3.02 |
| PPOF-4 | 0.91 | 5.14 | 3.36 | 13.43 | 8.27 | 3.02 |
| PPOF-5 | 1.21 | 4.84 | 3.36 | 13.43 | 8.27 | 3.02 |
| PPOF-6 | 1.51 | 4.54 | 3.36 | 13.43 | 8.27 | 3.02 |

## 3. Results

Table 2 and Table 3 display the outcomes of all kernelrazzo concrete samples' densities and thermal properties tests. The effect of density, and porosity on the thermal characteristics of kernelrazzo concrete is further discussed in stages.

### *3.1 Determination of Density for Kernelrazzo Concrete*

100 x 100 x 100 mm cubes were cast in accordance with Table 1 to measure density. These specimens were placed in water and allowed to cure for 7 or 28 days before their compressive strength could be assessed.

**Table 2**
Density (kg/m$^3$) for kernelrazzo concrete mixes

| Mix | Bulk Densities | |
|---|---|---|
| | 7-Days | 28-Days |
| PPOF-1 | 1880 | 1898 |
| PPOF-2 | 1862 | 1870 |
| PPOF-3 | 1874 | 1888 |
| PPOF-4 | 1775 | 1781 |
| PPOF-5 | 1767 | 1772 |
| PPOF-6 | 1745 | 1755 |

The results show that the density recorded by all specimens is in the range of 1745kg/m$^3$ - 1880kg/m$^3$ and 1755kg/m$^3$ – 1898Kg/m$^3$ at 7 and 28 days respectively. When the curing period is increased to 28 days, the density of all specimens rises. This is because a more compacted kernelrazzo concrete is created when cement and palm oil fuel ash are properly hydrated. Figure 1 showed the change in bulk densities of various mixes of kernelrazzo concrete at 3 and 28 days respectively with PPOF-1 showing optimum bulk density value of 1898 at day 28 and PPOF-3 with the second optimum value of 1888. This trend can be further noticed in Figure 1. The average bulk density for the various mix ranges from 1745Kg/m$^3$ to 1880Kg/m$^3$ and 1755Kg/m$^3$ to 1898Kg/m$^3$ for day 3 and 28 respectively.

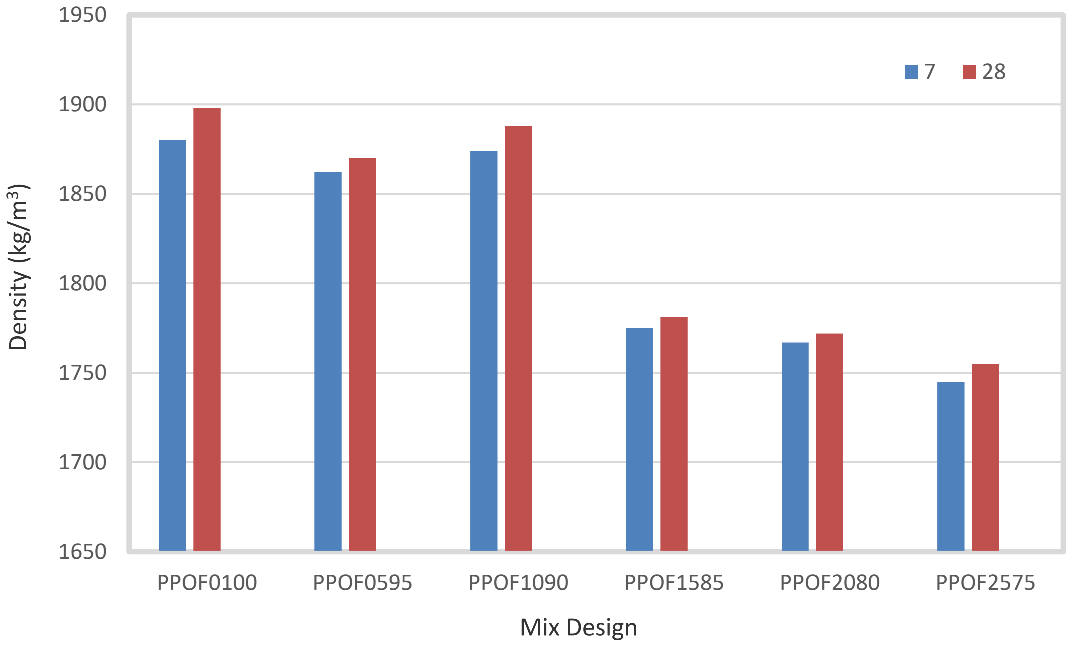


**Fig. 1.** Bar chart showing densities of kernelrazzo concrete

For evaluating the density of kernelrazzo concrete, 100 x 100 x 100 mm cubes were cast and cured for 7 and 28 days. Cubes were measured on electronic balance for density test. A bar chart was then plotted between densities and curing which has been computed at 7 and 28 days Their acquired moist density, de-moulding density, and oven-dry density are the densities under observation. The density attained while mixing before pouring the kernelrazzo concrete into the moulds is the wet density that was estimated. The densities that are employed are those that are reached after the concrete from kernelrazzo has dried and been demoulded. The kernelrazzo concrete mix's endurance and sustenance are determined using these densities. The expressions below are used to determine the density of specimens as in Eq. (1).

$$Bulk\ Density, \rho = \frac{Mass\ of\ sample}{Volume\ of\ the\ solid\ sample}$$

$$\rho = \frac{m_s}{V} \quad (1)$$

Where V = Volume of the specimen, in $m^3$, M is the mass of the specimen in the air in a saturated condition, in kg and $\rho$ is the density of the specimen.

### *3.2 Determination of Thermal Properties of Kernelrazzo Concrete*

After wet sieving, 40 x 40 x 20 mm cubes were cast and allowed to cure in water for 28 days to calculate the thermal characteristics of kernelrazzo concrete. The cubes are then equally split in half in the laboratory using a concrete cutting device. As seen in Figure 4, the tests were conducted using a Hot Disk TPS 2500 S system as shown in Figure 2 below. Thermal properties are determined for specific heat capacity, thermal diffusivity, and thermal conductivity in accordance with ASTM C518[49], ASM E1461 [50], and EN 1992 [51] respectively. The test was determined when they are 28 days. The list reading is the mean reading for three samples.

**Fig. 2.** Hot Disk TPS 2500S for thermal properties measurement

The significant thermal characteristics necessary for the design of structures are thermal expansion, specific heat capacity, thermal diffusivity, and thermal conductivity. Thermal conductivity (k) of a material is the ability to conduct heat through its internal structures and it depends on temperature, density, and the moisture content. Concrete made from kernelrazzo has the following thermal properties: conductivity, specific heat, diffusivity, and coefficient of expansion. The following Eq. (2) defines and estimates the relationship between conductivity, diffusivity, and specific heat:

$$Thermal\ conductivity, k = \frac{Thermal\ diffusivity}{Heat\ stored} = \frac{\alpha}{\rho c_p} \quad (2)$$

where k is the thermal conductivity (W/(m.K)), ρ is the density ($kg/m^3$) of the specimen, $c_p$ is the specific heat capacity (J/(kg.K)) and α is the thermal diffusivity ($m^2/s$).

The ability of a material to transfer heat is measured by its thermal conductivity (k), which is determined by multiplying the heat flow by the temperature gradient. The elements of thermal conductivity include thermal diffusivity, specific heat, and material density [52]. The low thermal conductivity value of the concrete is an advantageous for the buildings' thermal insulation. Thermal conductivity is used to evaluate a material's ability to transport heat in building insulation [53]. The transitory thermal reaction of a material to a change in temperature is measured by thermal diffusivity (α). The pace at which heat dissipates as temperature changes over time is connected to the physical relevance of thermal diffusivity [54]. Specific heat capacity (c) measures the ability index of concrete to experience temperature changes. Concrete having a high specific heat is beneficial for improving a structure's thermal stability [55]. Table 3 lists the thermal conductivity, specific heat, and thermal diffusivity of three samples.

**Table 3**
Thermal properties of kernelrazzo concrete

| Mix Design | Thermal Conductivity (W/(m.K)) | Thermal diffusivity ($m^2$/s) | Specific Heat Capacity (J/kg.K) |
|---|---|---|---|
| PPOF-11 | 1.075 | 1.458 | 0.811 |
| PPOF-12 | 1.518 | 1.299 | 1.345 |
| PPOF-13 | 1.559 | 1.331 | 1.452 |
| PPOF-14 | 1.304 | 1.223 | 1.218 |
| PP0F-15 | 1.131 | 1.146 | 1.201 |
| PPOF-16 | 1.127 | 0.905 | 0.942 |

Figure 3 shows the thermal properties of kernelrazzo concrete. PPOF1090 has highest value of thermal conductivity with 1.559 W/mK and the least by PPOF0100 with 1.075 W/mK. PPOF0100 has the highest thermal diffusivity with 1.458 $m^2$/s and the PPOF2575 with least value of 0.905$m^2$/s while PPOF1090 has the highest value of 1.452J/kgK and lowest value of 0.811J/kgK for PPOF0100 as the specific heat capacity.

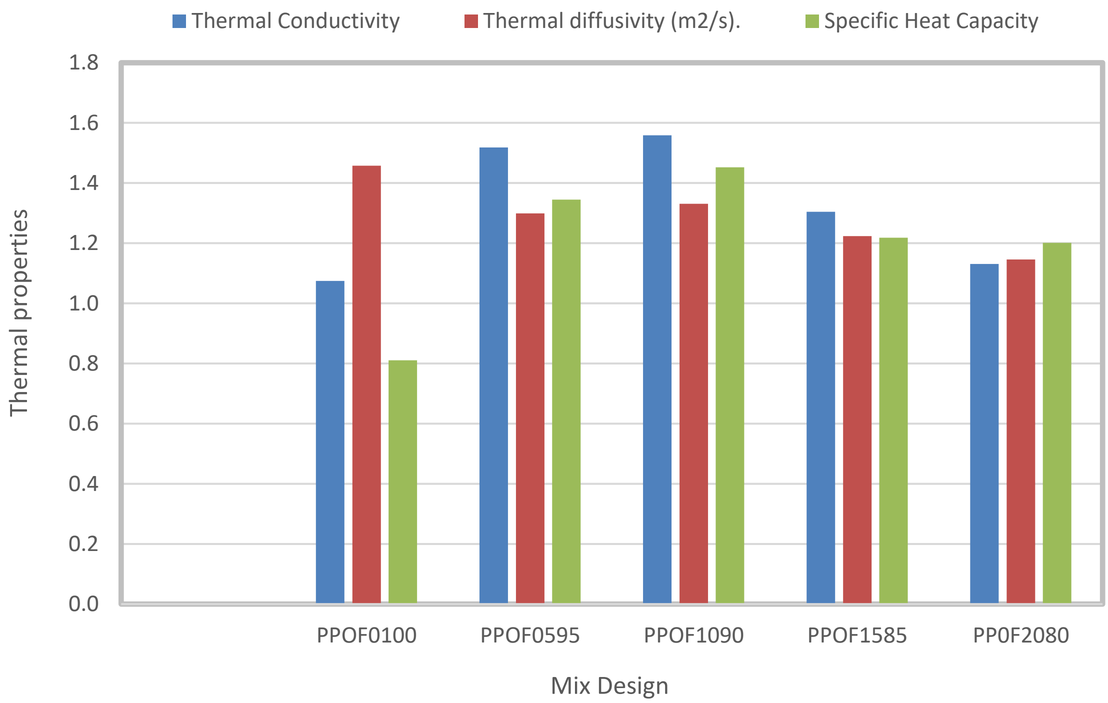


**Fig. 3.** Thermal properties of kernelrazzo concrete at day-28

### *3.3 Relationship of Density on Thermal Properties of Kernelrazzo Concrete*

Thermal characteristics are connected to a response that is material-dependent when heat is applied to a solid, liquid, or gas. The density of kernelrazzo concrete has an inverse relationship with its thermal characteristics. The three basic thermal parameters that will be evaluated are thermal conductivity, thermal diffusivity, and specific heat capacity. Thermal conductivity is only moderately influenced by density. Thermal conductivity and density appear to be connected. Heat should move more freely from atom to atom if the atoms were packed closely together. However, the atomic weight of the nucleus is the characteristic that is most closely related to density. The heat transfer average distance will decrease with an increase in bulk density, which will also result in a reduction in thermal conductivity. Figure 4 depicts this relationship for the thermal characteristics of cement kernelrazzo concrete at 28 days of age (W/mK) as a function of density.

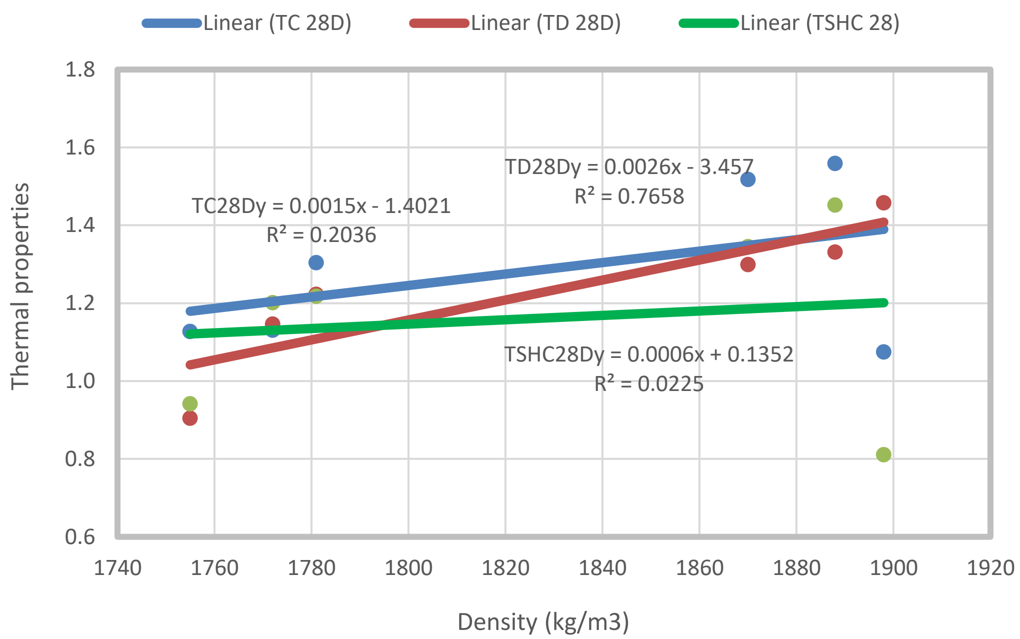


**Fig. 4.** Relationship for thermal properties as a function of density at day-28 of age for kernelrazzo concrete

Figure 4 depicts relationships that are exponential in nature. Sánchez-Calderón *et al.,* [55] discovered from his research that thermal conductivity rises with density and discovered a linear relationship between thermal characteristics when stated in (W/m.K) with density (kg/m$^3$). The relationships in Figure 4 are best represented by Eq. (3):

$$f_{TC28D} = 0.0015_{\gamma} - 1.402 \quad (3)$$

where $f_{TC28D}$ is the thermal capacity reading expressed by energy changes with its density at 28 days and $\gamma$ is the corresponding density observation at the same age. Eq. (3) yielded $R^2$ values of 0.2036; demonstrating a minimal correlation between the two factors.

Thermal diffusivity is the speed at which temperature disperses across a substance. It gauges how quickly heat moves through a medium. It gauges the amount of heat that moves from a hot material to a cool one. The thermal diffusivity unit in the SI is m$^2$/s. The rate of heat transfer from a substance's hot side to its cold side is measured using the substance or material's thermal diffusivity, which is calculated by dividing its specific heat capacity at constant pressure by its density and thermal conductivity. Figure 4 displays the thermal diffusivity as a function of density. Eq. (4) is the equation that best captures the relationships:

$$f_{TD28D} = 0.0026_{\gamma} - 3.457 \tag{4}$$

where $f_{TD28D}$ is the thermal diffusivity reading expressed by energy changes with its density at 28 days and $\gamma$ is the corresponding density reading at the same age. Eq. (4) yielded $R^2$ values of 0.7658; showing a relatively weak connection between the two variables.

A substance's specific heat capacity is calculated by dividing its mass by the heat capacity of a specimen of material. Its density, which is proportional to atomic density, determines its specific heat capacity. The specific heat capacity of a material is measured in J/(kg K) or J/(kg °C), and it is the amount of heat (J) absorbed per unit mass (kg) of the material as its temperature rises by 1 K (or 1 °C). Specific heat capacity, or just specific heat, is the measurement of a pure heat capacity per unit mass. The relationship between specific heat capacity and density is seen in Figure 4. Eq. (5) best captures the relationships:

$$f_{SHC28D} = 0.0006_{\gamma} + 0.135 \tag{5}$$

where $f_{SHC28D}$ is the specific heat capacity reading expressed by energy changes with its density at 28 days and $\gamma$ is the corresponding density reading at the same age. Eq. (5) produced $R^2$ values of 0.0225, indicating that there is only a negligibly strong correlation between the two variables.

## 4. Conclusions

From the outcomes of the research findings, an excellent substitute for marble chips and cement in the production of kernelrazzo concrete is palm kernel shell and palm oil fuel ash. The results showed that the thermal conductivity, specific heat, and thermal diffusivity of the constructed samples had decreased at 28 days as a result of a drop in kernelrazzo concrete weight brought on by an increase in PKS and POFA percentages, respectively. The interaction between water and temperature may have caused the kernelrazzo concrete's thermal characteristics to decline. Similarly, it can be discovered that kernelrazzo concrete inclusion of 10% POFA with 20% PKS and 80% marble chippings achieved a good and higher reading than the control sample. It was possible to see how water can increase thermal conductivity in porous building elements. It is advised that to lower the cost of cement, consideration be given to the use of PKS as a partial replacement for marble chips and palm oil fuel ash as a partial replacement for cement when using kernelrazzo.

## Acknowledgment
This research is not funded by any grant.

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