Effect of Palm Kernel Shell and Palm Oil Fuel Ash on Drying Shrinkage Properties of Kernelrazzo Concrete

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Abstract
The Effect of palm kernel shell and palm oil fuel ash on drying shrinkage properties of kernelrazzo concrete is the study's main goal. Kernelrazzo concrete 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 serious effect on the drying shrinkage of kernelrazzo concrete by conducting a scan of the literature and specifications. In this study, experiments in the laboratory were carried out at Concrete Laboratory. 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 prism samples after proper curing, the study involved estimating density, specific heat, thermal diffusivity, and thermal conductivity. Kernelrazzo concrete samples each measured 75 x 75 x 280 mm were made at six separate mix design series that have been designed and tested namely PKMC0100, PKMC1090, PKMC2080, PKMC3070, PKMC4060, and PKMC5050. The DoE method was used to compute the water and mechanically mix the components in a concrete mixer. Quarry dust, marble chips, and palm kernel shell were well mixed before cement and POFA, the binding agent, were added. The whole mixture was then properly mixed, and water was added. The drying shrinkage readings for the kernelrazzo concrete samples were taken up until 180 days after the first reading following de-moulding. It is concluded and suggested that PKS be used in place of some marble chips and palm oil fuel ash be used in place of some cement while utilizing kernelrazzo in order to reduce the cost of cement.

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Keyword Palm kernel shell, palm oil fuel ash, drying shrinkage, kernelrazzo concrete

1.0 Introduction

In building construction and housing development, the use of palm kernel shell as lightweight concrete (PKSC) has only recently begun to gain widespread awareness. The by-product produced by the oil palm industry facility is unquestionably significant, has commercial potential, and is environmentally beneficial (Sinaga et al., 2018. In the building industry, alternative materials that are comparatively less expensive and accomplish almost the same aims as the traditional ones are growing in popularity as a result of the tightening financial situation. A building is a device made specifically for the safety and habitation of humans. Examples of construction technology have all contributed to a significant and forward-thinking shift in modern architecture (Islam, 2018). In the built environment, a house's social, commercial, and cultural appeal are influenced by its quality and lengthy history. Basic comfort metrics and interior occupancy criteria must also be included. Examining the relationship between the developed environment's value and quality and human health, society, the economy, and the environment (Carmona, 2019).

The influence of increased cement substitution by POFA is investigated in connection to the durability properties of kernelrazzo concrete floor coatings. Water absorption, porosity, and aggregate impact resistance are the durability attributes that were investigated. The tests that were performed are detailed in the sections that follow.

Kernelrazzo concrete is a mixture of marble chips, regular Portland cement, quarry dust, structures include schools, hospitals, mosques, churches, commercial and industrial buildings, public buildings, housing estates, silos, domes, and more (Chew, 2017). Infrastructure facilities include things like neighbourhood maintenance standards, the design of public spaces, the range of land uses, the accessibility and closeness to common areas, and the availability of recreational possibilities (Piyapong et al., 2019; Deraman et al., 2022; Schulz et al., 2018; Wang et al., 2016). One of the main goals of a structure must be to protect it against environmental degradation brought on by air movement, radiation, chemical and biological attack, moisture, temperature, or natural disasters like fire or flood (Chu, 2017). The use of complex designs, newly introduced flooring materials as kernelrazzo concrete, and sophisticated palm oil fuel ash (POFA), water, and palm kernel shell. It is comparable to two partial substitutions: PKS for marble chips and the palm oil fuel ash (POFA) fraction for cement. Another novel material is kernelrazzo concrete floor finish, which is made by combining marble chips, quarry dust, regular Portland cement, palm oil fuel ash (POFA), and palm kernel shell. Kernelrazzo concrete floor finish is a type of terrazzo floor finish where palm kernel shells have been used in place of some or all of the marble chips (Arowojolu et al., 2019; Ayangade et al. 2004; Olusaola et al., 2015; Yalley, 2018). However, as the floor finish is made from the shell of a palm kernel, it might be more accurately referred to as kernelrazzo. Kernelrazzo is the process of replacing some or all of the marble chippings in terrazzo with palm kernel shells. Because palm kernel shells are more porous than traditional aggregates, their free and compressed bulk densities range from

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around 500 to 550 kg/rn^3 and 590 to 620 kg/m^3, respectively. According to these density arrays, palm kernel shells weigh nearly 60% less than typical coarse materials and these densities of the shell fall within the range of the majority of commonly used lightweight aggregates (Chai et al., 2017; Kareem et al., 2022; Oladiran et al., 2020; Purwanti et al., 2019). 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/m3 due to the lower density of PKS (Aslam et al., 2017; Oti et al., 2017). The palm kernel shells' density is in the middle of that of usual lightweight materials, and their specific gravity ranges from 1.14 to 1.37. The concrete's strength steadily declines as more oil palm shell is added. In the studies of (Belmokaddem et al., 2020; Ahmad and Yahya, 2016), the density of concrete steadily decreased as the quantity of substitute oil palm shell increased (Belmokaddem et al., 2020), and it was determined that 10% palm kernel shell in both water-to-cement ratios can be used as a substitute hard material in lightweight concrete. This is because most of them cannot be used for concrete due to its low strength requirements. Several writers have previously investigated PKS's properties as a lightweight material to produce lightweight concrete (Abolagba and Osuji, 2018; Zawawi et al., 2020; Azunna, 2019; Ogedengbe, 1985). The porous aggregate known as palm kernel shell (PKS) has a porosity of roughly 37% (Okpala, 1990). Porosity was discovered to be one of the factors affecting the thermal conductivity of lightweight concrete (Arriagada, 2019; Gao et al., 2021; Koçyigit et al., 2016; Li et al., 2017; Misri et al., 2017; Mydin et al, 2022; Ouali, 2009; Real, 2016). 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 drying shrinkage.

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. Palm oil fuel ash (POFA) is obtained from the burning of palm oil trash for the purpose of generating electricity in power plants has special qualities as pozzolanic material useful as a binder or supplementary and as partial replacement of a cement, POFA is a localized responsive material with strong pozzolanic inclinations, and which shows adequate micro-filling capabilities (Khasib & Nik Daud, 2020). POFA is typically disposed of in landfills, which causes an annual increase in ashes deposits and has now become a environmental hazards. Malaysian Palm Oil Board (MPOB) maintained that Malaysia has over 5.07 million hectares of palm oil plantations, according to the. The United States Department of Agriculture, the production of palm oil in 2016 and 2017 predicted that 64.5 million metric tonnes of palm oil would be produced and Palm oil fuel ash (POFA) is one of the major by-products of the palm oil industry, and it is produced by burning waste materials such as palm oil fiber, kernels, empty fruit bunches, and shells in power plants to generate electricity. Africa and Asian countries produce the majority of the world's palm oil. Burning waste materials such palm oil fibre, kernels, empty fruit bunches, and shells in power plants to

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produce energy yields palm oil fuel ash (POFA), a significant by-product of the palm oil industry. As the production of palm oil rises over time, so does the amount of POFA. Malaysia is one of the world's leading producers and exporters of palm oil. It is anticipated that Malaysia will produce more than 10 million tonnes of POFA annually.

The main objective is to promote kernelrazzo as a sustainable material to the public for its durability, flexibility, and timeless 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 (Sakthivel, 2018; ASTM, C150, 2012). Cement increases the fastening characteristic of concrete (Pacewska, Barbara, and Iwona Wilińska, 2020). The cement used for this study was produced by Tasek Corporation Berhard having a specific gravity of 3.15 g/cm³. Blaine's specific surface area for this cement was 3510 cm2/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 (Huseien et al., 2018). 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 (2012) 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 (Neville , 2004). 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 utilized as an inert filler to produce the study's samples, was purchased from a material merchant in Penang, Malaysia. A large percentage of

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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 (2003) 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 (2012).

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 (2012).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 (1980) 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

A number of observations were obtained during the formulation of the kernelrazzo concrete mixtures. These observations include the actual water demand, the PKS, MC, and QD quantities required to achieve the design density, and the measured fresh density. Palm kernel shell, marble chips, cement, quarry dust, actual water demand, base mix density, and measured fresh densities are the ingredients of kernelrazzo concrete mixes, which are listed in Table 1.

The kernelrazzo concrete samples utilized in this experimental study were made with tap water. Kernelrazzo concrete samples each measured 75 x 75 x 280 mm were made at six separate mix design series that have been designed and tested namely PKMC0100, PKMC1090, PKMC2080, PKMC3070, PKMC4060, and PKMC5050. The DoE method was used to compute the water and mechanically mix the components in a concrete mixer. Quarry dust, marble chips, and palm kernel shell were well mixed before cement and POFA, the binding agent, were added. The whole mixture was then properly mixed, and water was added.

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 PKMC0100 through PKMC5050 were created to achieve a goal compressive strength of 30 MPa at 28 days. For a few minutes, the cement, POFA, PKS, and marble chips were combined in the mixer. Water was then progressively added until the appropriate compactions were achieved. Mixing was considered complete when a homogeneous mixture was achieved. In each case, the inside of the plastic mould was coated with mould oil before casting to guarantee easy demoulding and a flawless surface finish. The wet material was cast immediately after mixing, poured into the moulds using a hand trowel, and compacted on a vibratory table.

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

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Sample	Binding agent (kg)		Coarse aggregate (%)		Coarse aggregate (kg)		Quarry Dust (kg)	Water (kg)
	POFA	Cement	PKS	MC	PKS	MC		
PFCM0100	0.00	1. 59	20	80	0.88	3. 53	2.17	0.79
PFCM0595	0.08	1.51	20	80	0.88	3. 53	2.17	0.79
PFCM1090	0.16	1.43	20	80	0.88	3. 53	2.17	0.79
PFCM1585	0.24	1.35	20	80	0.88	3. 53	2.17	0.79
PFCM2080	0.32	1.27	20	80	0.88	3. 53	2.17	0.79
PFCM2575	0.40	1.19	20	80	0.88	3. 53	2.17	0.79

3. Results

Table 2 and Table 3 display the effect of PKS on drying shrinkage and effect of POFA on drying shrinkage outcomes of all kernelrazzo concrete samples' durability properties tests. The effect of PKS, and POFA on the durability characteristics of kernelrazzo concrete is further discussed in stages.

3.1 Determination of drying shrinkage for Kernelrazzo Concrete

Prisms of 75 x 75 x 280mm are used to determine the drying shrinkage. Readings of drying shrinkage were taken in accordance with BS ISO 1920-8 (2009) shrinking as it dries as in Figure 1. To simulate the actual conditions that the finished product will experience, the shrinkage specimens were left outside under cover. The drying shrinkage readings for the kernelrazzo concrete samples were taken up until 180 days after the first reading following de-moulding.

Figure 1: Drying shrinkage Comparator for Top Readings

$$\textbf{Drying Shrinkage}, \varepsilon = \frac{\textbf{Original wet measurement} - \textbf{Dry measurement}}{\textbf{Dry length } (280)} \times 100$$

$$\textbf{\textit{Initial Drying Shrinkage}}, \varepsilon = \frac{L_1 - L_2}{L} \times 100 \quad (1)$$

Where: L_1 = Wet length, L_2 = Dry measurement, L_0 = Dry length (280)

3.2.Effect of palm kernel shell (PKS) on drying shrinkage

In this part, the drying shrinkage readings was demonstrated. Due to the increased palm kernel shell content in kernelrazzo concrete, there is poor cohesion, and inadequate compaction, kernelrazzo concrete has significant shrinkage due to inability to compact properly. Readings on shrinkage were conducted up to 180 days after the concrete had been placed since drying shrinkage is crucial to kernelrazzo concrete. According to earlier research, PKS concrete drying shrinkage rises as the amount of palm kernel shell (PKS) increased. Figure 2 reveals the relationship

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between drying shrinkage and curing age for cement kernelrazzo concrete among the various mixes. Figure 2 illustrates the drying shrinkage for the mixes of PKMC0100, PKMC1090, PKMC2080, PKMC3070, PKMC4060, and PKMC5050 respectively. (Aslam et al., 2016) stated from the earlier studies revealed that increase in the percentage of palm kernel shell in kernelrazzo concrete also gives rise in the drying shrinkage of the kernelrazzo concrete. The need to reduce the high-rate dry shrinkage in the kernelrazzo concrete is to reduce the volume of palm kernel shell to be utilized. As a risk that may likely to occur will include among others are differential shrinkage which may leads fractures to grow, spread, and eventually come together, causing concrete to fail.

Table 2 explain dry shrinkage for kernelrazzo concrete produced only with cement as binder without pozzolanic materials. When the sample was uncovered to a dry environment, the particles have a propensity to shift nearest to one another as the water evaporates to the atmosphere, which results in the shrinkage.

Table 2:Drying shrinkage of cement kernelrazzo concrete (%)

Mix	**Curing Age (Days)**						
	0	**7**	**14**	**28**	**56**	**90**	**180**
PKMC0100	**0**	**0.56**	**0.59**	**0.62**	**0.65**	**0.68**	**0.71**
PKMC1090	**0**	**0.58**	**0.62**	**0.67**	**0.69**	**0.73**	**0.76**
PKMC2080	**0**	**0.61**	**0.65**	**0.71**	**0.75**	**0.77**	**0.79**
PKMC3070	**0**	**0.63**	**0.71**	**0.74**	**0.78**	**0.81**	**0.83**
PKMC4060	**0**	**0.65**	**0.73**	**0.78**	**0.81**	**0.85**	**0.87**
PKMC5050	**0**	**0.69**	**0.76**	**0.82**	**0.84**	**0.88**	**0.91**

It showed persistent increase in drying shrinkage as the volume of palm kernel increases. PKMC0100 to PKMC5050 gave 0.56, 0.58, 0.61, 0.63, 0.65 and 0.69 at 7 days and 0.71, 0.76, 0.79, 0.83, 0.87 and 0.91) at 180 days respectively and applicable to all days of testing .

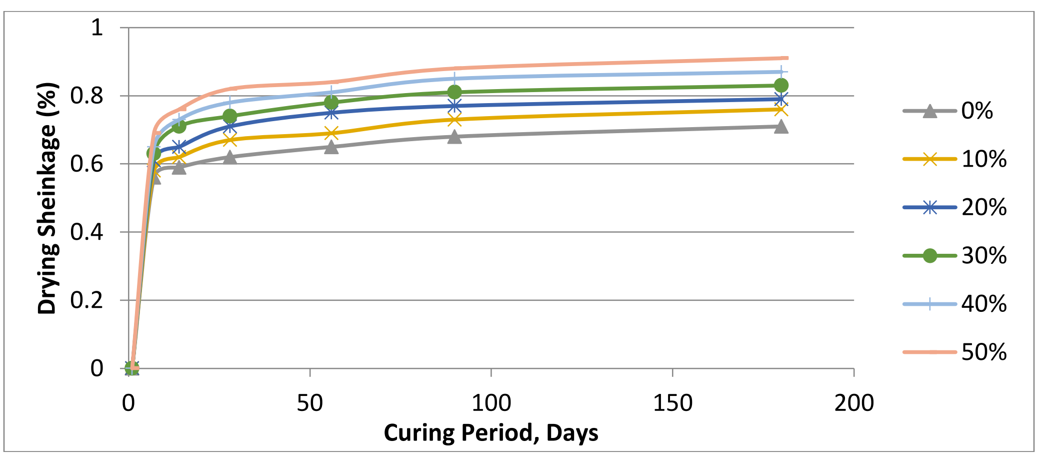

Figure 2: Drying shrinkage of cement kernelrazzo concrete (%)

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For a given ordinary Portland cement (OPC) kernelrazzo concrete, increase in the volume of PKS gave rise to the rate of drying shrinkage. PKMC5050 (0.91) has the highest shrinkage values compared with the control PKMC0100 (0.71) at 180 days. There is a rise in drying shrinkage of cement kernelrazzo concrete that had higher volume of PKS than that of the least PKS, PKMC0100 had 37.50% increase from 7 to 180 days while PKMC1090, PKMC2080, PKMC3070, PKMC4060, and PKMC5050 possess 42.42%. 53.33%, 46.43%, 56% and 86.61% increase from 7 to 180 days respectively.

3.3.Effect of palm oil fuel ash (POFA) on drying shrinkage

Palm oil fuel ash (POFA) is an excellent pozzolanic material since it includes a lot of SiO_2. It enhances the compressive strength of concrete, reduces drying shrinkage as well as increases workability of concrete (H. M. Hamada, Jokhio, Yahaya, & Humada, 2018).

Table 3: Drying shrinkage of POFA kernelrazzo concrete (%)

Mix	Curing Age (Days)						
	1	7	14	28	56	90	180
PFCM0100	0	0.52	0.66	0.71	0.74	0.77	0.81
PFCM0595	0	0.42	0.54	0.62	0.66	0.69	0.72
PFCM1090	0	0.39	0.49	0.55	0.6	0.62	0.64
PFCM1585	0	0.37	0.44	0.49	0.53	0.56	0.58
PFCM2080	0	0.35	0.39	0.45	0.51	0.53	0.56
PFCM2575	0	0.34	0.36	0.42	0.49	0.52	0.53

Table 3 shows the effect of palm oil fuel ash on drying shrinkage. According to earlier research, concrete's drying shrinkage reduced as the amount of palm oil fuel ash increased as drying shrinkage reduces.

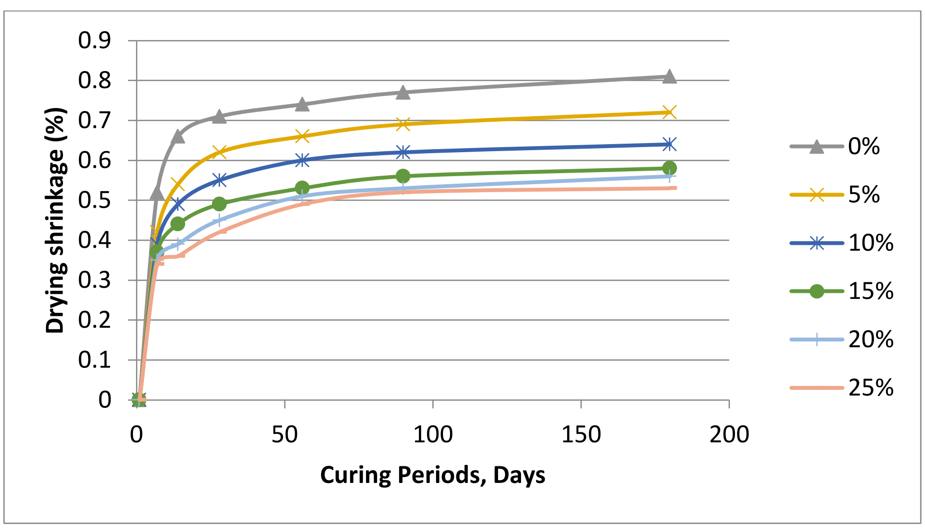

Figure 3: Drying shrinkage of POFA kernelrazzo concrete (%)

Kernelrazzo concrete mix with samples PFCM0100, PFCM0595, PFCM1090, PFCM1595, PFCM2080 and PFCM2575 respectively Figure 3 and using POFA substitute levels revealed decreases in drying shrinkage readings that fall on drying

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shrinkage of the mix PFCM0100, and PFCM2575 kernelrazzo concrete specimens at 1, 3, 7, 14, 28, 56, 90 and 180-days of curing was 0, 0.52, 0.66, 0.71, 0.74, 0.77, 0.81% and 0, 0.34, 0.36, 0.42, 0.49, 0.52, 0.53%, respectively. The results showed that 25% POFA had highest controlled decreases in drying shrinkage.

POFA kernelrazzo concrete, increasing POFA substitution stages have a positive impact on drying shrinkage and this research gave reduction in drying shrinkage, it showed that POFA had significant influence on drying shrinkage. Therefore, drying shrinkage decreased with rising POFA value. Numerous studies by (Alsubari et al., 2014; H. M. Hamada, Jokhio, Yahaya, & Humada, 2018) have demonstrated that palm oil fuel ash (POFA) containing concrete outperforms cement (OPC) by reducing the drying shrinkage of the kernelrazzo concrete.

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 for all the mix ratios, the drying shrinkage of the kernelrazzo prism specimens increased with curing age but decreased with percentage replacement of PKS and POFA with cement. For a given ordinary Portland cement (OPC) kernelrazzo concrete, increase in the volume of PKS gave rise to the rate of drying shrinkage. POFA kernelrazzo concrete, increasing POFA substitution stages have a positive impact on drying shrinkage and this research gave reduction in drying shrinkage, it showed that POFA had significant influence on drying shrinkage. 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 is suggested that PKS be used in place of some marble chips and palm oil fuel ash be used in place of some cement while utilizing kernelrazzo in order to reduce the cost of cement.

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