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Original Research Article

Impact of Petroleum Products on Strength Properties of Concrete Produced from Using Lateritic Sand and Quarry Dust at Optimum Mix

Enang Egbe[1]*, Christiana Agri[2], Nnaemeka Nwele[2], David Oliver[2], Ezekiel Atang[2]

[1]Department of Civil Engineering, University of Cross River State
[2]UG- Department of Civil Engineering, University of Cross River State

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***Corresponding author:** Enang Egbe
Department of Civil Engineering, University of Cross River State

Abstract

This study examined how petroleum products (petrol, kerosene, and diesel) affect the strength of concrete made with lateritic sand and quarry dust. A 1:1½:3 mix with a 0.65 water–cement ratio and 25% lateritic sand plus 75% quarry dust was used. Thirty-nine 100 mm cubes were water-cured for 7–28 days, then immersed in petroleum products for 30–60 days. Water-cured cubes showed steady strength gains up to 15.74 N/mm² at 28 days. In contrast, exposure to petroleum products reduced strength: after 30 days, averages were 12.89 N/mm² (petrol), 11.36 N/mm² (kerosene), and 13.30 N/mm² (diesel); after 45 days, 12.78, 14.19, and 13.53 N/mm² respectively. Petrol caused the greatest deterioration, kerosene moderate, and diesel the least. Petroleum exposure disrupted cement hydration, increased porosity, and weakened the paste–aggregate bond, reducing durability. The study recommends protective coatings, improved mix designs, and strict management in fuel-contaminated environments such as filling stations and garages.

Keywords: Quarry dust, Laterite, Compressive strength, petroleum products.

1.0 INTRODUCTION

Concrete remains the most widely used construction material globally due to its versatility, durability, and relative cost-effectiveness (Neville, 2011). As a composite material, it plays a vital role in infrastructure development across both developed and developing regions. However, the performance and longevity of concrete structures are often compromised by environmental and chemical exposures—particularly in areas susceptible to hydrocarbon contamination.

Petroleum-based products such as kerosene, petrol, diesel, and crude oil frequently infiltrate construction environments through leaks, spills, or improper disposal associated with machinery and industrial processes. These contaminants can significantly impair concrete's mechanical properties, including its compressive, tensile, and flexural strengths (Oti, Kinuthia, & Bai, 2018; Al-Gahtani, 2008). Recent research confirms that even small concentrations of petroleum contamination can have marked effects on concrete. For example, Oyelami *et al.,* (2024) found that oil-contaminated sand reduced compressive strength by approximately 44% at 10% contamination and 81% at 20% contamination levels, while Elinwa and Mahmoud (2023) observed that gasoline and gas-oil exposure altered the hydration process and increased sorptivity in modified concrete mixtures.

The presence of petroleum products in concrete—either through direct exposure of hardened structures or contamination of raw materials—can disrupt the cement hydration process, weaken the bond between cement paste and aggregates, and alter the pore structure of the concrete matrix (Adewole, Ajagbe, & Arasi, 2015; Elinwa & Mahmoud, 2023). These effects can also manifest in reduced density, increased permeability, and higher weight loss over time (Ali *et al.*,2022). Moreover, petroleum hydrocarbons can become physically entrapped within the cementitious matrix, influencing both durability and leachability characteristics (Okafor *et.al.*,2023).

These effects are further complicated when alternative fine aggregates are introduced into the mix. With increasing emphasis on sustainable and locally sourced construction materials, lateritic sand and quarry dust are being adopted as substitutes for conventional river sand (Osinubi, Eberemu, & Ojekunle, 2016). Lateritic sand, abundant in tropical regions, is rich in iron and aluminum oxides, while quarry dust, a by-product of stone crushing, offers both environmental and economic benefits (Mustapha & Jimoh, 2019). Several recent studies demonstrate that replacing river sand with lateritic soil or quarry dust can yield comparable or even improved mechanical properties (Edeh *et al.*,2022; Okonkwo *et.al.*,2021). However, the chemical and physical characteristics of these materials—such as clay content, angularity, and absorption capacity—may influence how concrete responds to petroleum product exposure (Mustapha & Jimoh, 2019; Eprints.lmu.edu.ng, 2023).

Despite growing research on sustainable concrete materials, there remains a critical gap in understanding how these alternative fine aggregates interact with petroleum contaminants. In regions where oil production and industrial activity are prevalent, concrete structures are often exposed to hydrocarbons over prolonged periods. Yet, the specific effects of such exposure—particularly on concrete containing lateritic sand and quarry dust—are inadequately documented (Nwankwo *et.al.*,2024). Studies have suggested that the absorption characteristics and surface texture of fine aggregates may either mitigate or exacerbate the detrimental effects of hydrocarbons on concrete (Adewole *et.al.*,2015; Mustapha & Jimoh, 2019).

This study therefore seeks to investigate the effects of selected petroleum products—kerosene, petrol, and diesel—on the compressive strength of concrete made with lateritic sand and quarry dust as fine aggregate replacements. Understanding these interactions is essential for improving the resilience of concrete structures in oil-contaminated environments. The findings will inform construction practices in industrial and petroleum-rich regions, where hydrocarbon exposure poses a constant threat to infrastructure durability (Oyelami *et.al.*,2024; Elinwa & Mahmoud, 2023).

2.0 REVIEW OF RELATED STUDIES

The deleterious effects of petroleum-based products such as diesel, kerosene, and crude oil on concrete strength are well documented. These hydrocarbons interfere with the cement hydration process, hinder the development of a strong bond between cement paste and aggregates, and often result in a weaker interfacial transition zone (Wilson *et.al.,*2001). When concrete or its constituents (particularly fine aggregates) are contaminated with petroleum products, a significant reduction in compressive strength is typically observed.

Osuji and Nwankwo (2015) investigated the effect of crude oil contamination on concrete by varying the oil content within the fine aggregate and reported compressive strength reductions of up to 50% depending on contamination level. They attributed this reduction to poor hydration and weakened paste-aggregate bonding caused by the presence of oil films on aggregate surfaces. Similarly, Obayes (2017) noted that even at 6% contamination with crude oil, concrete compressive strength dropped substantially, while workability increased due to the lubricating effect of the oil.

Ogbonna and Abubakar (2019) studied concrete cured in crude oil-contaminated water and observed that increasing the oil concentration in curing water resulted in progressive reductions in compressive, tensile, and flexural strengths. This confirmed the susceptibility of concrete's mechanical properties to petroleum pollutants, especially during early hydration phases.

Kerosene and diesel also display similar effects. Oti *et al.,* (2018) noted that diesel-contaminated concrete specimens exhibited decreased mechanical performance, with diesel acting as a barrier to proper hydration. The severity of strength reduction often depends on the type of petroleum product, degree of contamination, and timing of exposure (Wilson *et.al.,*2001).

In parallel with concerns about contamination, the replacement of conventional river sand with alternative fine aggregates such as lateritic sand and quarry dust has gained momentum, particularly in tropical regions where these materials are locally available and cost-effective. However, these materials can influence concrete properties due to their unique physical and chemical characteristics.

Ambrose *et al.,* (2017) investigated the compressive strength of concrete made with various proportions of lateritic sand and quarry dust and observed that the inclusion of lateritic sand generally reduced compressive strength compared to conventional mixes, especially at higher replacement levels. The reduction was attributed to the high clay content and fines in lateritic materials, which affect water demand and paste-aggregate bonding.

Folagbade and Osadola (2010) evaluated the workability and absorption characteristics of laterized concrete and concluded that the use of lateritic sand necessitated lower water/cement ratios or the inclusion of water-reducing admixtures to maintain desirable properties. Excessive fines and high-water absorption associated with laterite can lead to poor workability and reduced strength.

Furthermore, Ahmad *et al.,* (2018) reported that replacing river sand with quarry dust up to 30% improved the compressive strength of self-compacting concrete, while further replacement led to reductions due to excessive fines and higher water demand. Quarry dust, due to its angular shape and relatively high silica content, enhances interlocking within the concrete matrix at optimal replacement levels.

These findings suggest that while lateritic sand and quarry dust can serve as viable alternatives to river sand, their incorporation must be carefully optimized to ensure structural adequacy.

Despite the extensive research on petroleum-contaminated concrete and the separate body of work on lateritic and quarry dust concrete, there is a significant gap in the literature examining the interaction between petroleum contamination and these alternative fine aggregates.

To date, most petroleum contamination studies (e.g., Osuji & Nwankwo, 2015; Obayes, 2017; Ogbonna & Abubakar, 2019) have used conventional river sand. The behavior of lateritic sand and quarry dust in petroleum-exposed concrete remains largely unexamined. This is a critical oversight, as these materials possess different surface textures, clay content, and absorptive capacities, which could influence how hydrocarbons interact with the cementitious matrix.

3.0 MATERIALS AND METHOD

3.1.1Fine and Coarse Aggregate (Gravel)

The lateritic soil for the investigation was collected from a borrow-pit in Nyanghasa, Calabar Municipal Local Government Area, Cross River State, Nigeria. The coarse aggregate used was crushed granite of igneous origin with size range of 9-12mm. The coarse aggregate and quarry dust that also form part of fine aggregate were obtained from Saturn Quarry, located in Akamkpa Local Government Area of Cross River State, Nigeria. The material were purchased in bulk and transported to the Strength of Materials Laboratory, University of Cross River State, Calabar.

3.1.2 Petroleum Products

The petroleum products utilized in this current study were obtained from UDDY KING Filling Station, Murtala Mohammed Highway, Calabar, Nigeria on Latitude 05’43.3” and Longitude 012’8.26”. They were kept in air tight plastic containers to prevent losses and pollution.

3.1.3 Cement

Ordinary Portland Cement (UNICEM brand) conforming to the requirements of BS EN 197-1 (1995) was used. The cement, classified as grade 42.5N, was procured from a local dealer along New Airport Road, Ekpo Abasi, in Calabar South Local Government Area, Cross River State. It was transported to the laboratory and stored in a clean, dry environment to prevent contamination and premature hydration.

3.1.4 Water

Clean potable water obtained from the water tank located at the Microbiology and Strength of Materials Laboratories, University of Cross River State, Calabar, was used for both mixing and curing of the concrete cubes. Using the same water source ensured consistency throughout the experimental process.

3.2 Sample Preparation and Exposure to Petroleum Products

Concrete specimens were prepared following standard laboratory procedures for batching, mixing, casting, curing, and exposure testing. The mix design used a ratio of 1:1.5:3 (cement:fine aggregate:coarse aggregate) with a water–cement ratio of 0.65, incorporating 25% lateritic sand and 75% quarry dust as fine aggregates as pre-determined by Ukpata *et al.*, (2012)

All materials were air-dried and mixed in a mechanical mixer to ensure uniformity. The fresh concrete was placed into 100 × 100 × 100 mm steel cube moulds in three compacted layers and finished with a steel trowel. After 24 hours of setting, specimens were demoulded and cured in clean water for 7, 14, 21, and 28 days in accordance with BS EN 12390-3 (2009).

Cured cubes were subsequently immersed in petrol, kerosene, and diesel for 30, 45, and 60 days in sealed, labeled containers to prevent contamination and evaporation. After each exposure period, specimens were cleaned, air-dried, and subjected to compressive strength testing to assess the effects of petroleum exposure on the concrete’s mechanical performance and durability.

3.3 Experimental Investigation and Setup

Experimental investigations, including sieve analysis and compressive strength testing, were conducted at the Strength of Materials Laboratory, University of Cross River State (UNICROSS), Calabar, Nigeria. Concrete specimens were prepared and tested using the optimum mix proportion of 1:1.5:3 with a water–cement ratio of 0.65, incorporating 25% lateritic sand and 75% quarry dust as fine aggregates adopted from the study carried out by Ukpata *et.al.*,(2012). All experimental procedures followed standard laboratory practices to ensure reliability and reproducibility of results.

3.4 Compressive Strength Determination

Compressive strength tests were conducted in accordance with BS EN 12390-3 (2009) using a digital compression testing machine with a maximum capacity of 2000 kN. Each concrete cube, measuring 100 × 100 × 100 mm, was placed centrally on the machine’s loading platform, and load was applied uniformly at a controlled rate until failure occurred. The maximum load at failure was recorded, and the compressive strength of each specimen was calculated using the relation:

$$\mathbf{fc} = \frac{P}{A} \qquad \text{equation 3.1}$$

where fc is the compressive strength (N/mm^2), P is the maximum load at failure (N), and A is the loaded area of the cube (mm^2). The average of three specimens was taken as the representative compressive strength for each test condition.

4.0 RESULTS AND DISCUSSION

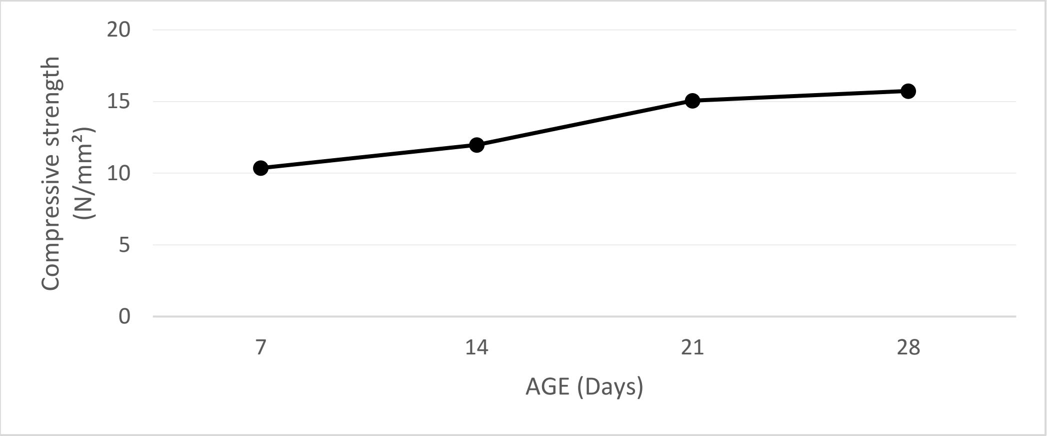

Figure 1: Variation of compressive strength with days of curing.

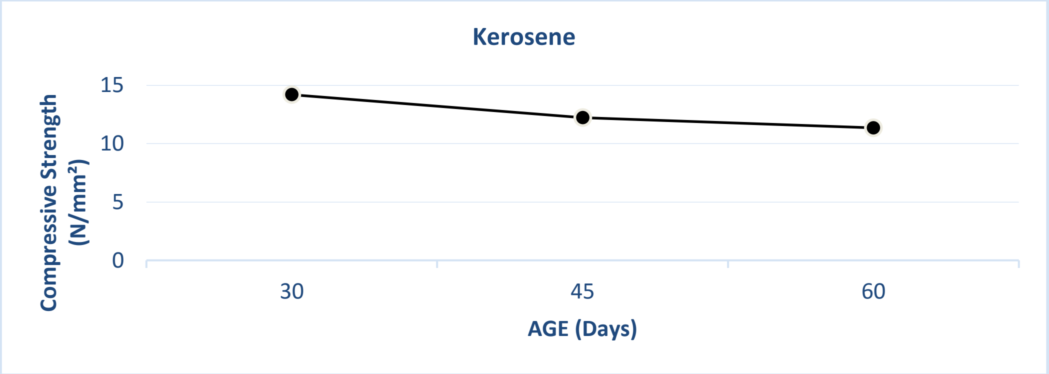

Figure 2: Variation of compressive strength with age for cubes immerse in Kerosene

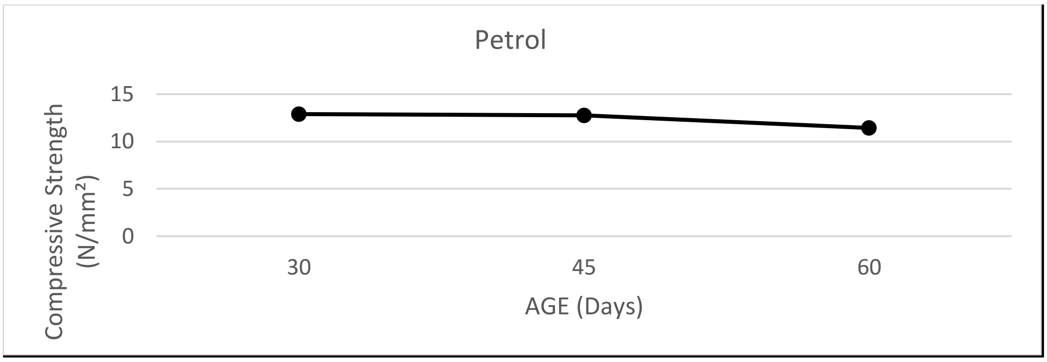

Figure 3: Variation of compressive strength with age for cubes immerse in Petrol

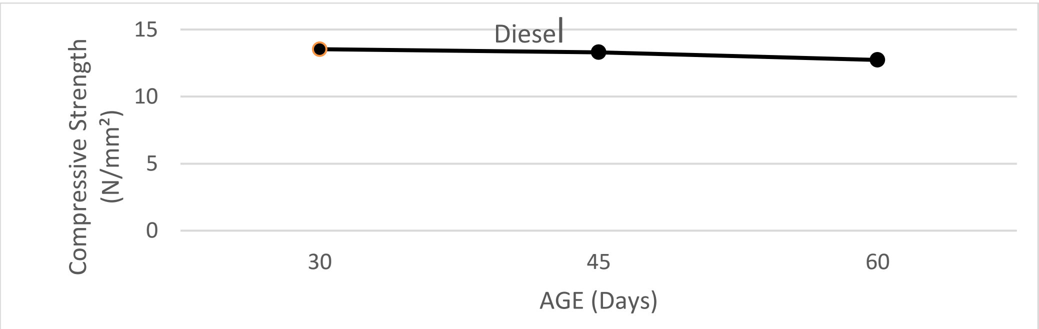

Figure 4: Variation of compressive strength with age for cubes immerse in Diesel

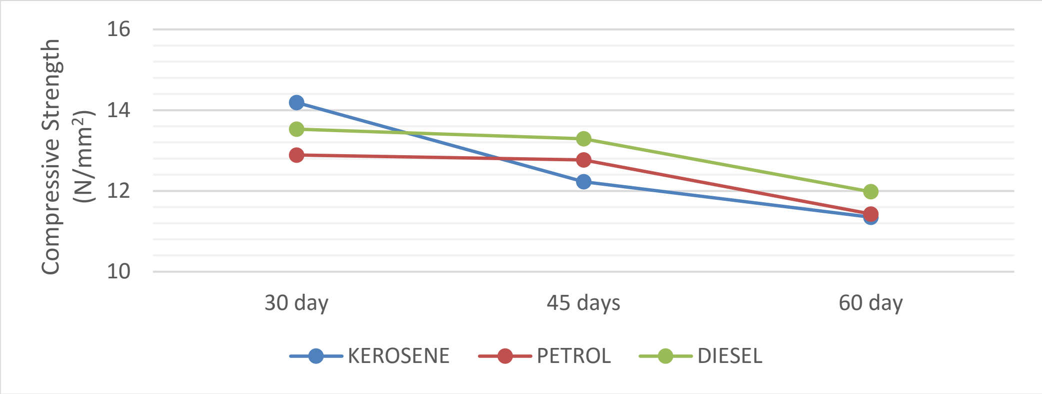

Figure 5: Comparison Effect of Different Petroleum Products on Concrete strength

4.1 Compressive Strength of Water-Cured Specimens

Figure 1 shows the variation in compressive strength of concrete specimens cured in water. The results show a consistent increase in compressive strength with curing age, rising from 10.36 N/mm² at 7 days to 11.99 N/mm² at 14 days, 15.06 N/mm² at 21 days, and 15.74 N/mm² at 28 days. This steady strength development can be attributed to the ongoing hydration of cement, which continues to form additional calcium silicate hydrate (C–S–H) gel, thereby enhancing the bond between the cement paste and aggregates (Neville & Brooks, 2010; Saka *et.al.*,2022; Mehta & Monteiro, 2014). As hydration progresses, the internal structure of the concrete becomes denser, reducing porosity and leading to improved mechanical performance (Mindess, Young, & Darwin, 2003).

4.2 Impact of Petroleum Products on Compressive Strength of concrete.

Figures 2,3 and 4 shows the variation of compressive strength with age for cubes immerse in different petroleum product media (kerosene, petrol and diesel). The Concrete specimens exposed to petroleum products exhibited a marked decline in compressive strength compared to the water-cured control samples. After 30 days of immersion, the average compressive strengths were recorded as 12.89 N/mm² for petrol exposure, 11.36 N/mm² for kerosene, and 13.30 N/mm² for diesel. At 45 days, the respective values were 12.78 N/mm², 14.19 N/mm², and 13.53 N/mm². These variations indicate that the chemical constituents of petroleum products—particularly hydrocarbons and aromatic compounds—interfere with the hydration process of cement and the stability of the calcium silicate hydrate (C–S–H) matrix. Similar findings have been reported by Oyenuga et al. (2019), who observed reductions in compressive strength of concrete exposed to petrol and diesel due to the penetration of hydrocarbons, which disrupt the pore structure and reduce bond strength. Likewise, Alhassan and Mohammed (2017) noted that kerosene exposure leads to microstructural degradation and leaching of hydration products. Overall, prolonged contact with petroleum products impairs the integrity of the cement matrix and weakens the load-bearing capacity of concrete structures

4.3 Comparison of the effect Different Petroleum Products on Concrete strength.

Figure 5 shows the comparison of the compressive strength for cubes immersed in different petroleum product. Among the petroleum products, petrol caused the highest reduction in strength, followed by kerosene, while diesel showed the least detrimental effect. Petrol's high volatility and solvent properties may accelerate the leaching of calcium compounds and weaken the cement matrix. Kerosene's moderate effect suggests partial penetration, whereas diesel's higher viscosity limits absorption, thereby minimizing its impact**.** The decline in compressive strength is attributed to the disruption of cement hydration, increased porosity, and degradation of the paste–aggregate bond. Petroleum hydrocarbons may infiltrate the concrete matrix, displacing water and hindering ongoing hydration reactions. This leads to the formation of microcracks and a reduction in cohesive strength. Over prolonged exposure, such deterioration can significantly compromise structural performance**.**

These findings highlight the vulnerability of concrete structures in petroleum-contaminated environments such as filling stations, garages, and oil-producing regions. Protective measures such as impermeable floor coatings, optimized mix designs with supplementary cementitious materials, and rigorous site management—are recommended to mitigate long-term degradation and maintain structural integrity.

5.0 CONCLUSION AND RECOMMENDATIONS

This study investigated the effects of petroleum products, petrol, kerosene, and diesel on the compressive strength of concrete prepared with lateritic sand and quarry dust as fine aggregates. The results demonstrated that water-cured concrete exhibited steady strength development with curing age, while exposure to petroleum products caused a reduction in compressive strength. Petrol had the most pronounced detrimental effect, followed by kerosene, with diesel showing the least impact. The observed strength reductions were attributed to disruption of cement hydration, increased porosity, and weakening of the paste–aggregate bond.

The findings underscore the structural risks associated with petroleum exposure in environments such as filling stations, garages, and oil-producing regions. To mitigate these effects, the use of impermeable coatings, optimized concrete mix designs with supplementary cementitious materials, and strict site management practices is recommended. Future research could explore long-term durability and alternative protective materials to enhance concrete resilience in hydrocarbon-contaminated environments.

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