EFFECTS OF USED ENGINE OIL ON PRODUCTION OF HIGH-STRENGTH CONCRETE

Abstract

This research addressed the dual challenge of sustainable waste management through the reuse of used engine oil and the continuous demand for innovative high-strength concrete (HSC) production methods. The aim of this study was to investigate the effects of used engine oil on production of high-strength concrete. A detailed set of experiments was conducted involving the production and testing of full-scale reinforced concrete beams. The beams were cast using concrete mixes with a controlled dosage of superplasticizer, and their performance was compared with that of test mixes produced using varying dosages of used engine oil. The tests included fresh concrete properties such as slump and air content, as well as hardened properties including compressive, flexural, and splitting tensile strengths. The data obtained from the experimental tests underwent comprehensive analysis. This included plotting load–deflection curves and assessing the compressive strength, flexural strength, and tensile strength of both the control and test beams, cubes, and cylinders. Cracking patterns were also documented. At 56 days, the control mix achieved a compressive strength of 53.8 MPa, while mixes containing 0.15% and 0.30% used engine oil recorded 39.2 MPa and 25.7 MPa, representing reductions of 27.14% and 60.1%, respectively. The slump values increased from 210 mm (control) to 230 mm and 240 mm, showing a 9.52% –14.29% improvement in workability. The flexural strength load decreased from 57.08 kN (control) to 52.65 kN and 43.11 kN, indicating reductions of 7.76% and 24.47%, respectively. Similarly, splitting tensile strength loads changed from 96.48 kN (control) to 105.29 kN and 92.72 kN, showing a slight increase at 0.15% but a minor drop at 0.30%. The findings indicate that the incorporation of used engine oil enhances the workability of high-strength concrete but leads to a significant reduction in compressive and flexural strengths as the dosage increases. A low dosage of 0.15% used engine oil provided a limited improvement in workability and splitting tensile performance, though with a noticeable compromise in compressive strength, while a 0.30% dosage proved detrimental to overall mechanical performance. Consequently, used engine oil is not suitable as an admixture for high-strength structural concrete where strength is critical, but may be cautiously considered at very low dosages for non-structural applications where improved workability and sustainability benefits are prioritized.

Keywords

Used engine oil, High-strength concrete, Sustainable construction, Reinforced concrete, Mechanical properties, Workability

1. Introduction

The construction industry increasingly relies on high-strength concrete (HSC) due to its superior mechanical performance and durability, particularly for infrastructure requiring high load-bearing capacity and long service life. However, sustainability concerns have driven research toward incorporating waste materials into concrete to reduce environmental impact (Aïtcin, 2003; Puertas et al., 2021). Used engine oil (UEO) is a significant environmental pollutant generated in large quantities from vehicular and industrial machinery, posing serious risks to soil, water, ecosystems, and human health if improperly disposed of (IJRIAS, 2023; Okoh et al., 2001). Prior studies indicate that while small quantities of UEO may enhance concrete workability, they can adversely affect compressive strength after hardening (Oyekan and Kamiyo, 2011; Bilal and Ahmad, 2002; Bilal and Ahmad, 2003). Recent advances in engineering modelling and materials performance analysis have further expanded our understanding of how chemical admixtures alter concrete microstructure and mechanical response (Sundaram et al., 2024; Priya et al., 2024). Characterisation methods at the micro- and nanoscale also provide deeper insight into how interfacial zones and surface morphology evolve in modified concrete systems (Ţălu, 2015).

Despite growing interest in alternative materials, limited attention has been given to the behaviour of UEO in high-strength concrete systems, which differ markedly from conventional concrete due to their use of mineral admixtures and chemical superplasticizers. The introduction of UEO into such highly engineered mixtures may influence hydration, bonding, microstructure, and durability in ways not yet fully understood (Mehta and Monteiro, 2014; Shafiq et al., 2011). Improper disposal of waste oil further exacerbates environmental degradation, particularly in aquatic environments where toxic hydrocarbons and heavy metals threaten ecosystems and public health (Okoh et al., 2001; Cvengros et al., 2023). Although reprocessing and controlled destruction methods exist, the use of UEO as an admixture in concrete has been proposed as a potential waste-management strategy, though experimental validation remains insufficient (El-Fadel and Khoury, 2001). Emerging machine learning and AI-assisted performance prediction models (Deng et al., 2025; Chen et al., 2025) have also been applied to construction material modelling, indicating that data-driven approaches can complement experimental programmes. This study seeks to address the gap in knowledge by systematically evaluating the influence of UEO, as an additional admixture, on the workability and mechanical properties of high-strength reinforced concrete at multiple curing ages.

2. Materials and methods

2.1 Materials

This study employed an experimental research design to evaluate the influence of used engine oil (UEO) on the fresh and hardened properties of high-strength concrete under controlled laboratory conditions. Concrete mixes incorporating UEO at dosages of 0.15% and 0.30% by weight of cement were prepared and compared with a control mix containing only a superplasticizer. The materials used included cement, natural sand, crushed coarse aggregates, potable water, steel reinforcement, used engine oil, and a commercial superplasticizer (CHRYSO). Standard laboratory equipment such as cube and cylinder moulds, a compression testing machine, dial gauges, and full-scale reinforced concrete beam moulds were employed to assess workability and mechanical performance. Eighteen reinforced concrete beams with uniform dimensions of 100 × 100 × 400 mm were cast, reinforced with high-yield steel bars and stirrups, cured, and tested for flexural behaviour at 28 and 56 days. The UEO was sourced from a local automobile workshop, filtered before use, and introduced alongside a constant superplasticizer dosage of 0.88% by weight of cement, ensuring that observed performance variations could be attributed solely to the presence and dosage of used engine oil.

2.2 Mix Design

Concrete mixes were designed to achieve a target characteristic compressive strength of 50 MPa at 56 days using the Department of Environment (DOE) mix design method, as prescribed by BS 8110-1:1997. A water–cement ratio of 0.47, Portland cement Class 42.5 (conforming to BS EN 197-1), and a maximum aggregate size of 20 mm were adopted. The target mean strength was determined using a standard deviation of 8 MPa and a defective rate of 2.5% (k = 1.96). Free water content was fixed at 225 kg/m³, resulting in a cement content of approximately 478.7 kg/m³. Crushed coarse aggregate and uncrushed fine aggregate were used, with total aggregate content of about 1675 kg/m³, proportioned as 40% fine aggregate and 60% coarse aggregate. A commercial superplasticizer (CHRYSO) was added at a constant dosage of 0.88% by weight of cement. It is important to clarify that used engine oil (UEO) was incorporated as an additional admixture — not as a replacement for any existing ingredient — at dosages of 0% (control), 0.15%, and 0.30% by weight of cement. All other mix parameters were held constant to ensure that observed variations in performance could be directly attributed to the presence and dosage of UEO. Concrete specimens comprised 150 × 150 × 150 mm cubes, 100 × 100 × 400 mm reinforced beams, and 100 mm diameter × 200 mm height cylinders, cast and tested at curing ages of 7, 14, 28, and 56 days. Compressive strength tests were conducted on cubes and cylinders at all four curing ages. Flexural strength tests were performed on beams at 28 and 56 days; however, the 7- and 14-day compressive strength results are presented in the Results section to provide a complete picture of early-age strength development.

Table 1(a): Mix Proportions per Cubic Metre (kg/m³)

Mix ID	W/C	Cement	Fine Aggregate	Coarse Aggregate	Superplasticizer	UEO
Control	0.47	478.72	670.51	1005.77	4.21	0
0.15% UEO	0.47	478.72	670.51	1005.77	4.21	0.718
0.30% UEO	0.47	478.72	670.51	1005.77	4.21	1.436

Table 1(b): Batch Quantities per Specimen (kg)

Specimen Type	Mix ID	Water	Cement	Fine Aggregate	Coarse Aggregate	UEO
Cube (150×150×150 mm)	Control	0.759	1.616	2.263	3.395	0
	0.15%	0.759	1.616	2.263	3.395	0.0024
	0.30%	0.759	1.616	2.263	3.395	0.0048
Beam (100×100×400 mm)	Control	1.013	2.154	3.016	4.523	0
	0.15%	1.013	2.154	3.016	4.523	0.0032
	0.30%	1.013	2.154	3.016	4.523	0.0065
Cylinder	Control	0.353	0.752	1.052	1.578	0
	0.15%	0.353	0.752	1.052	1.578	0.0011
	0.30%	0.353	0.752	1.052	1.578	0.0011

2.3 Batching, Mixing, and Casting

Concrete constituents were batched by weight and mixed mechanically to ensure accuracy and uniformity, beginning with dry mixing of cement and aggregates followed by the controlled addition of water and admixtures to achieve a homogeneous mix. Fresh concrete was cast into lubricated steel moulds in layers, compacted by tamping, surface-finished, and left for 24 hours before demoulding and water curing at ambient temperature for 7, 14, 28, and 56 days in accordance with BS 1881: Part 125. A high-range water-reducing superplasticizer (CHRYSO® ZA 1538-01) was used at a constant dosage of 0.88% by weight of cement to enhance workability without compromising durability. Flexural test results were normalized using the compressive strength of companion cubes at corresponding ages to minimize variability and enable direct comparison between control and used engine oil (UEO) mixes, with normalized flexural strength expressed as the ratio of beam flexural strength to cube compressive strength. The used engine oil was sourced from an automobile workshop, filtered before use, securely stored during experimentation, and disposed of after testing in line with safe laboratory and environmental handling practices. See figure 1 below

Figure 1: Casting of cubes, cylinders and beams

2.4 Tests on Fresh and Hardened Concrete

The workability of fresh concrete was assessed using the slump test in accordance with BS EN 12350-2 (2009). For each mix (control, 0.15% UEO, and 0.30% UEO), freshly mixed concrete was placed in a standard slump cone in three equal layers, with each layer compacted using 25 strokes of a rounded tamping rod to remove air pockets. After levelling the top surface, the cone was lifted vertically, allowing the concrete to settle under its own weight. The difference in height between the mould and the settled concrete, called the slump value, indicated the mix's workability. The setting time of the cement–UEO paste was determined using the Vicat apparatus following ASTM C191 (2013). Pastes of standard consistency were placed in the Vicat mould, and the penetration of the needle was checked at intervals. The initial setting time was recorded when the paste began losing plasticity, while the final setting time was noted when the paste became completely rigid. For hardened concrete, flexural strength was measured on beams of 100 mm × 100 mm × 400 mm using a Compression Testing Machine. Each specimen was loaded at a uniform rate until failure, and the maximum load was recorded at 28 and 56 days. The flexural strength, σ, was calculated using Eq. 1 as follows:

$$\sigma = \frac{FL}{wd^2}\ \text{N/mm}^2 \quad \text{(Eq. 1)}$$

where F is the maximum applied load, L is the length of the beam, w is the width, and d is the depth. This test evaluated the beam's resistance to bending.

Split tensile strength was determined using cylindrical specimens of 100 mm diameter and 200 mm height. Specimens were placed horizontally in a Compression Testing Machine, and load was applied until splitting along the vertical axis occurred. The maximum load at failure was recorded, and the split tensile strength, f_t, was calculated using Eq. 2 as follows:

$$f_t = \frac{2P}{\pi DL}\ \text{N/mm}^2 \quad \text{(Eq. 2)}$$

where P is the load at failure, D is the cylinder diameter, and L is its length. This method provides an indirect measure of the concrete's tensile capacity.

Compressive strength was measured on 150 mm × 150 mm × 150 mm concrete cubes using a Compression Testing Machine. The load was gradually applied until failure, and the compressive strength, f_c, was calculated using Eq. 3 as follows:

$$f_c = P/A\ (\text{N/mm}^2) \quad \text{(Eq. 3)}$$

where P is the ultimate load at failure and A is the cross-sectional area of the cube. This test determines the concrete's resistance to axial compression.

3. Results and Discussions

Sieve analysis determined the particle size distribution of the fine aggregate in accordance with BS 882:1992. The fine aggregate was classified as Zone II sand based on its grading envelope, indicating medium-graded material suitable for structural concrete. The coefficients of uniformity and curvature were:

$$C_u = \frac{D_{60}}{D_{10}} = 4.898,$$

$$C_c = \frac{(D_{30})^2}{D_{10}D_{60}} = 0.566$$

indicating a well-graded sand.

Bulk density was calculated from the sample mass and cylinder volume:

$$\text{Mass} = 904.2 - 120.2 = 784\ \text{g},$$

$$V = \pi r^2 h = \frac{22}{7} \times 4.42^2 \times 10.8 = 656.87\ \text{cm}^3,$$

$$\text{Bulk Density} = \frac{784}{656.87} = 1.19\ \text{g/cm}^3$$

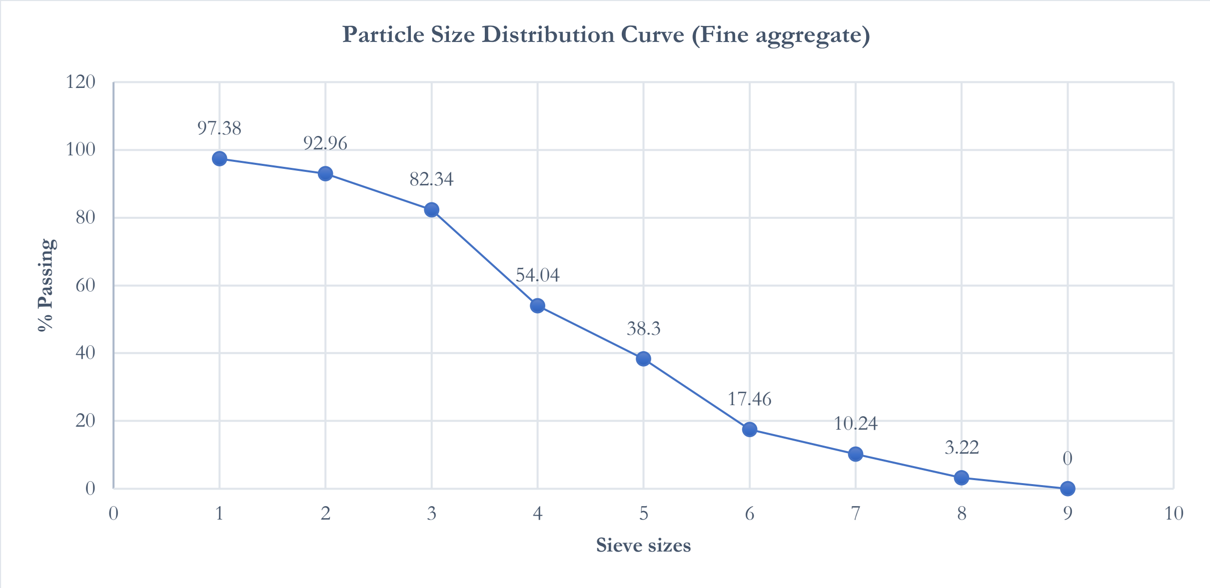

Figure 2: Particle Size Distribution Curve (Fine Aggregate)

Fine Aggregate: Specific gravity using the pycnometer method:

$$G_s = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)} = 2.7$$

Coarse Aggregate: Particle size distribution was determined via sieve analysis. Water absorption and specific gravity were:

$$\text{Absorption} = \frac{\text{SSD} - \text{Dry}}{\text{Dry}} \times 100 = 0.346\%,$$

$$G_s = \frac{\text{SSD}}{\text{SSD} - \text{Submerged}} = 2.65$$

Bulk density was calculated from container dimensions and mass:

$$V = \frac{\pi d^2}{4} \times h = 1.7851 \times 10^{-3}\ \text{m}^3,$$

$$\text{Bulk Density} = \frac{2.7374}{1.7851 \times 10^{-3}} = 1533.46\ \text{kg/m}^3$$

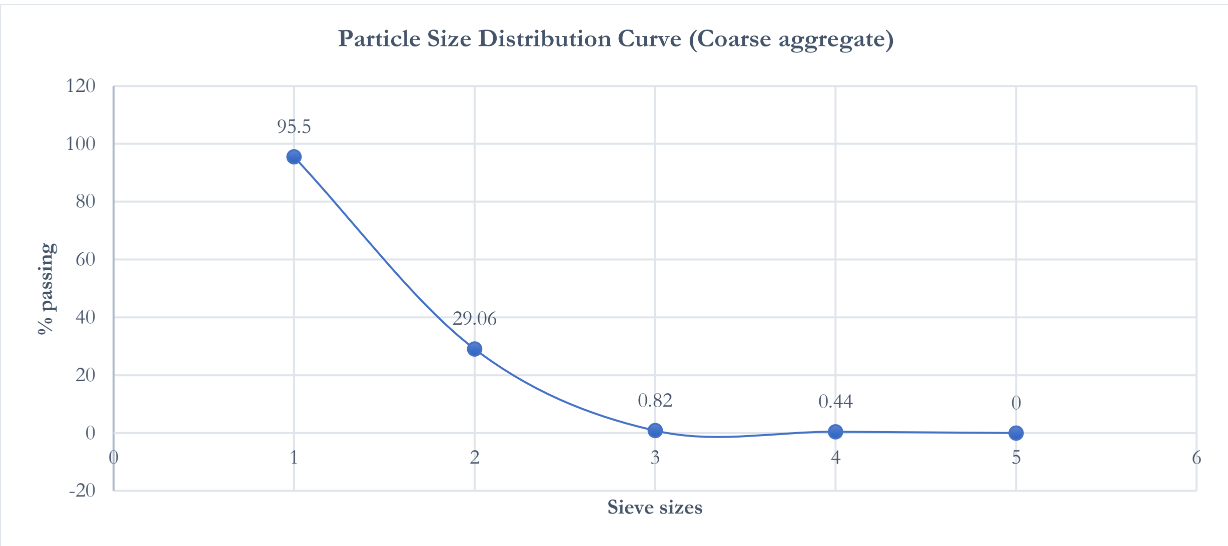

Figure 3: Particle Size Distribution Curve (Coarse Aggregate)

The aggregates exhibited strong mechanical performance, suitable for high-strength concrete. The Aggregate Crushing Value (ACV) and Aggregate Impact Value (AIV) were calculated as:

$$\text{ACV} = \frac{A - B}{A} \times 100 = \frac{2737.4 - 2251.2}{2737.4} \times 100 = 17.76\%$$

$$\text{AIV} = \frac{A - B}{A} \times 100 = \frac{363.5 - 336.5}{363.5} \times 100 = 7.43\%$$

Characterization of materials confirmed their suitability, with specific gravities of 2.70 (fine aggregate) and 2.65 (coarse aggregate), and low water absorption (0.346%), indicating dense, non-porous aggregates conducive to strength development.

Workability increased with UEO content, as shown by slump values: 210 mm (control), 230 mm (0.15% UEO), and 240 mm (0.30% UEO), representing increases of 9.5% and 14.3% respectively. These values, together with fresh density measurements, are summarised in Table 3. Fresh concrete densities were 2502, 2481, and 2593 kg/m³ for control, 0.15%, and 0.30% UEO mixes, respectively, influenced by micro-air voids and the lower density of oil (~0.85 g/cm³). The increase in workability is attributed to the lubricating effect of the oil film around aggregate particles, which reduces inter-particle friction and facilitates mix flow. This finding is consistent with observations by Shafiq et al. (2018), Oyekan and Kamiyo (2011), and Bilal and Ahmad (2002, 2003).

Hardened concrete compressive strength was determined by:

Table 3: Fresh Concrete Properties

Property	Control (0% UEO)	0.15% UEO	0.30% UEO
Slump (mm)	210	230	240
Fresh Density (kg/m³)	2502	2481	2593
Workability Class (BS EN 206)	S4	S5	S5

Hardened concrete compressive strength (Eq. 6) is repeated here for reference, with A = 150 × 150 = 22,500 mm²:

$$f_c = \frac{P}{A}, A = 150 \times 150 = 22{,}500 \text{ mm}^2$$

The compressive strength development across all curing ages is summarised as follows. The control mix achieved 29.0, 35.2, 43.5, and 49.6 MPa at 7, 14, 28, and 56 days, respectively, demonstrating consistent strength gain over time. The 0.15% UEO mix recorded 22.1, 28.4, 32.5, and 39.2 MPa at the same ages, while the 0.30% UEO mix achieved 14.3, 19.8, 19.7, and 25.7 MPa. Increasing UEO reduced strength consistently across all ages, with the 0.30% UEO mix showing a 48.2% reduction at 56 days relative to the control. Even at 7 days, UEO incorporation resulted in reductions of 23.8% (0.15%) and 50.7% (0.30%) compared to the control, confirming that UEO's detrimental effect on hydration begins at early ages. These results highlight that UEO improves workability but consistently compromises short-term and long-term compressive strength.

Statistical Analysis of Compressive Strength

The effects of UEO dosage and curing age on compressive strength were quantified using a multiple linear regression model. Statistical analyses were performed using R (version 4.3.1). Descriptive statistics (mean, standard deviation) were computed for all mechanical property measurements. One-way analysis of variance (ANOVA) was used to assess significant differences between mix groups, with pairwise comparisons conducted using Tukey's Honestly Significant Difference (HSD) post-hoc test at a significance level of $\alpha = 0.05$. A multiple linear regression was applied to model compressive strength as a function of UEO content and curing age, and model performance was evaluated using R^2, residual standard error, and the F-statistic. Additionally, Akima interpolation was employed to generate a three-dimensional strength surface for visual analysis:

$$\text{Compressive Strength} = \beta_0 + \beta_1(\text{UEO}) + \beta_2(\text{Day}) + \beta_3(\text{UEO} \times \text{Day}) \quad (Eq. 7)$$

The regression model was fitted using ordinary least squares (OLS) on a dataset of 12 observations (3 UEO levels × 4 curing ages), with compressive strength (MPa) as the dependent variable and UEO content (%), curing age (days), and their interaction as predictors. The model showed strong predictive performance with $R^2 = 0.9285$, adjusted $R^2 = 0.9017$, residual standard error = 3.24 MPa, and F-statistic = 34.62 ($p < 0.001$), indicating that over 92% of the variance in compressive strength is explained by UEO content, curing age, and their interaction.

Interpretation of the coefficients reveals:

Intercept ($\beta_0 = 28.18$ MPa): Theoretical baseline compressive strength at Day 0 with 0% UEO.

UEO effect ($\beta_1 = -37.65$ MPa/unit): Each 1% increase in UEO reduces compressive strength by ~37.65 MPa, confirming a significant detrimental effect (p = 0.021).

Day effect ($\beta_2 = +0.42$ MPa/day): Strength increases by ~0.42 MPa per day of curing ($p < 0.001$), reflecting ongoing cement hydration.

Interaction effect ($\beta_3 = -0.92$ MPa/unit UEO-day): Negative interaction, borderline significant (p = 0.054), indicates that UEO's strength-reducing effect intensifies over longer curing periods.

These results quantitatively confirm that while curing time enhances strength, the presence of UEO significantly undermines compressive strength, with its effect compounded over time.

Interpolated Strength Surface and Mechanisms of Strength Reduction

A three-dimensional surface generated via Akima interpolation illustrated the combined effects of UEO content and curing age on compressive strength. Akima interpolation is a shape-preserving, piecewise polynomial method that minimises oscillation in irregularly spaced datasets (Akima, 1970). It was preferred here over standard spline or linear interpolation because it avoids overshooting at data boundaries and handles the sparse experimental grid (3 UEO levels × 4 curing ages) reliably without requiring a large number of data points. The resulting surface shows a descending gradient with increasing UEO, confirming systematic strength reduction, and an ascending ridge with curing age, reflecting ongoing hydration.

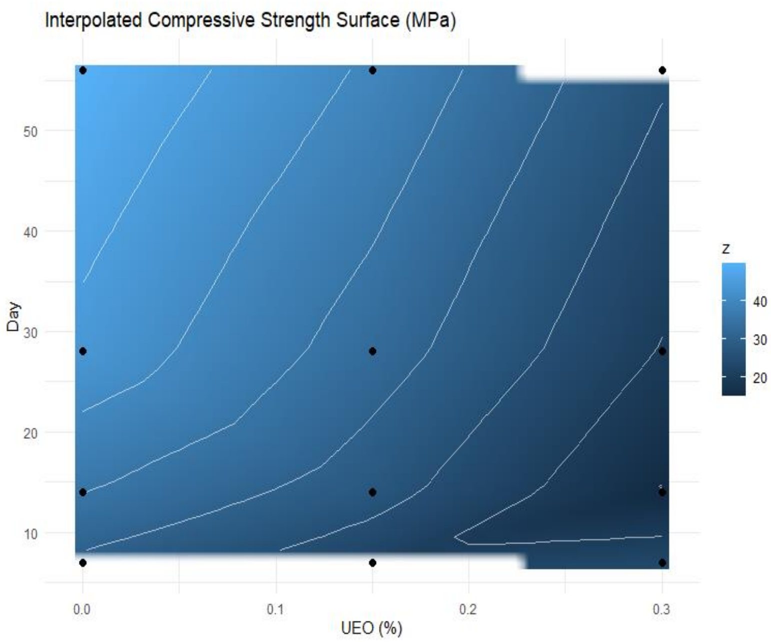

Figure 4: Akima interpolation of Strength Distribution

A pronounced depression at 0.30% UEO highlights the severe strength loss at higher oil dosages, particularly at later ages. The reduction in strength is attributed to several mechanisms: (i) Interfacial Transition Zone (ITZ) weakening, where UEO forms a hydrophobic film on aggregates, hindering cement-aggregate bonding; (ii) hydration interference, as the oil coating slows water access and retards cement reactions, consistent with longer setting times and the negative interaction effect; (iii) micro-void introduction, where trapped air reduces the solid load-bearing area; and (iv) reduced matrix density, as oil's lower density (~0.85 g/cm³) decreases the overall concrete compactness. Together, these factors explain the progressive compressive strength loss observed with increasing UEO content.

Flexural Strength Evaluation

Flexural strength of 100×100×400 mm beam specimens was tested at 28 and 56 days. At 28 days, the 0.15% UEO mix exhibited a notable increase in flexural strength (28.30 MPa, +57%) compared to the control (18.00 MPa), while the 0.30% UEO mix decreased to 13.95 MPa (-22%). By 56 days, all UEO-modified mixes showed lower flexural strengths than the control, with values of 13.40 MPa (0.15% UEO, -8%) and 11.00 MPa (0.30% UEO, -25%) relative to 14.60 MPa for the control.

The early-age improvement at 0.15% UEO is attributed to microstructural effects: limited internal lubrication promotes stress redistribution, controlled micro-void formation delays crack propagation, and increased matrix deformability enhances post-crack load-bearing capacity. These mechanisms improve ductility and bending resistance at low oil dosage. However, at higher dosages or later ages, UEO interferes with cement hydration and bond formation, weakening the interfacial transition zone and reducing flexural performance.

A regression model of the form:

$$\text{Flexural Strength} = \beta_0 + \beta_1(\text{UEO}) + \beta_2(\text{Day}) + \beta_3(\text{UEO} \times \text{Day}) \quad (Eq. 8)$$

showed poor statistical fit ($R^2 = 0.470$, adjusted $R^2 = -0.326$, p = 0.678), reflecting small sample size, high variability, and the non-linear response of flexural strength. Despite this, practical observations confirm the reproducible enhancement at 0.15% UEO, highlighting that low dosages can improve early-age flexural behavior even if longer-term effects are detrimental.

Split Tensile Strength Analysis

Cylindrical concrete specimens (100 mm × 200 mm) were tested at 28 and 56 days. At 28 days, the control mix recorded 2.933 MPa, while mixes with 0.15% and 0.30% UEO achieved 3.594 MPa (+22.5%) and 3.393 MPa (+15.7%), respectively. At 56 days, the control reached 3.071 MPa, with 0.15% UEO slightly higher at 3.351 MPa (+9.1%), whereas 0.30% UEO showed a marginal decrease to 2.951 MPa (-3.9%).

The initial improvement in split tensile strength with UEO is attributed to microstructural effects. Finely dispersed oil droplets act as compressible inclusions that bridge microcracks, absorb energy during crack propagation, and impart slight plasticity, reducing brittleness. Uniformly distributed micro-voids help redistribute tensile stresses, enhancing energy dissipation under the indirect tensile loading of the split test.

However, at 56 days, as the cement matrix densifies with continued hydration, the influence of UEO diminishes. The matured matrix strength dominates, and the interference of UEO with the interfacial transition zone (ITZ) increasingly offsets its crack-mitigating benefits, resulting in reduced tensile gains at later ages.

Flexural and Split Tensile Strength Results

The flexural and split tensile strength results at 28 and 56 days are tabulated below for clarity. These values underpin the comparative analysis presented in the subsequent section. All values represent the mean of three specimens per mix per age.

Table 4: Flexural and Split Tensile Strength at 28 and 56 Days (MPa)

Test	Age (days)	Control	0.15% UEO	0.30% UEO
Flexural Strength (MPa)	28	18.00	28.30	13.95
Flexural Strength (MPa)	56	14.60	13.40	11.00
Split Tensile Strength (MPa)	28	2.933	3.594	3.393
Split Tensile Strength (MPa)	56	3.071	3.351	2.951

Comparative Analysis of Mechanical Properties

A comparative evaluation of compressive, flexural, and split tensile strengths at 28 and 56 days revealed distinct and evolving effects of UEO on concrete performance. At **28 days**, compressive strength was most severely affected, decreasing from 43.5 MPa (control) to 32.5 MPa (0.15% UEO) and 19.7 MPa (0.30% UEO). In contrast, flexural and tensile strengths exhibited a temporary enhancement at 0.15% UEO, with flexural strength rising from 18.0 to 28.3 MPa (+57%) and tensile strength from 2.93 to 3.59 MPa (+23%).

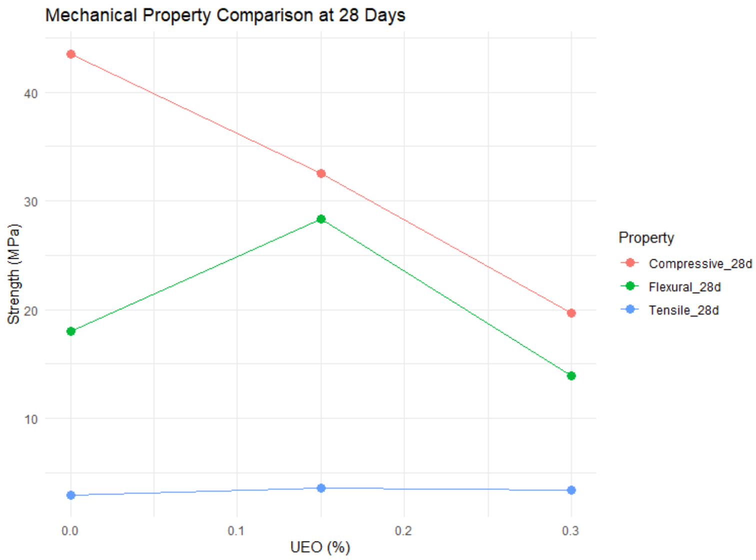

Figure 5: Mechanical Property Comparison at 28 days

This suggests a "sweet spot" at low UEO content where ductility benefits may outweigh compressive losses. At 0.30% UEO, all properties declined, indicating that this dosage exceeds the beneficial threshold.

By **56 days**, the trends evolved with concrete maturity. Compressive strength gains were observed for all mixes, but the relative deficit widened: 49.6 MPa (control), 39.2 MPa (0.15% UEO, −21%), and 25.7 MPa (0.30% UEO, −48%). Flexural strength advantages diminished; the 0.15% UEO mix dropped sharply from 28.3 to 13.4 MPa (−53%), reflecting the temporary nature of UEO's microstructural benefits, likely due to ITZ degradation and continued matrix densification. In contrast, **split tensile strength remained enhanced** at 0.15% UEO (3.35 MPa, +9%) and nearly equivalent to control at 0.30% UEO (2.95 MPa), indicating sustained mechanisms that improve crack resistance and ductility even as compressive and flexural properties decline.

Table 2: Summary of Mechanical Properties of Concrete Mixes at 28 and 56 Days

Property	Control	0.15% UEO	0.30% UEO
28d Compressive (MPa)	43.5 (100%)	32.5 (75%)	19.7 (45%)
28d Flexural (MPa)	18.0 (100%)	28.3 (157%)	14.0 (78%)
28d Split Tensile (MPa)	2.93 (100%)	3.59 (123%)	3.39 (116%)
56d Compressive (MPa)	49.6 (100%)	39.2 (79%)	25.7 (52%)
56d Flexural (MPa)	14.6 (100%)	13.4 (92%)	11.0 (75%)
56d Split Tensile (MPa)	3.07 (100%)	3.35 (109%)	2.95 (96%)

Conclusion and Discussion

This study investigated the effects of used engine oil (UEO) on high-strength concrete by incorporating 0%, 0.15%, and 0.30% UEO by weight of cement. Fresh properties, including slump, and hardened properties, compressive, flexural, and split tensile strengths, were evaluated over different curing periods.

The results indicate that UEO significantly enhances workability, with slump increasing from 210 mm (control) to 230 mm and 240 mm for 0.15% and 0.30% UEO, respectively. However, compressive strength declined with increasing UEO, decreasing from 53.8 MPa (control) to 39.2 MPa (0.15% UEO) and 25.7 MPa (0.30% UEO) at 56 days. Flexural strength and split tensile performance showed slight improvement at 0.15% UEO, suggesting a potential benefit for ductility and crack resistance, but both properties declined at 0.30% UEO.

Material characterization confirmed all aggregates and cement met high-strength concrete requirements, with fine aggregate specific gravity of 2.70 and well-graded sand (Cu = 4.898), and coarse aggregate demonstrating low water absorption (0.346%), ACV = 17.76%, and AIV = 7.43%.

A multiple linear regression model accurately predicted compressive strength:

Compressive Strength = 28.18 − 37.65(UEO) + 0.42(Day) − 0.92(UEO × Day), as presented in the Results section (Eq. 7). The model (R^2 = 0.9285, residual standard error = 3.24 MPa) confirmed that UEO's negative effect on compressive strength intensifies with curing age. Predicted values closely matched experimental results (deviation <1.6%, MAE = 2.18 MPa, RMSE = 3.24 MPa, MAPE = 8.3%).

Recommendation

Based on the findings of this study, it is recommended that used engine oil (UEO) should not be incorporated into high-strength concrete for structural elements where compressive strength is critical, as reductions of 21–48% at 56 days render it unsuitable for load-bearing applications. If UEO is to be used, its dosage should be strictly limited to a maximum of 0.15% by weight of cement, since higher proportions lead to unacceptable strength losses. At this optimal dosage, UEO-modified concrete may be appropriate for non-structural applications, such as sidewalks, driveways, and partition walls, where moderate strength and improved workability are advantageous. Further research is encouraged to evaluate long-term durability properties, including creep, shrinkage, chloride penetration resistance, and freeze-thaw performance over extended periods of 365 days or more. Finally, any potential environmental benefits of recycling UEO must be carefully weighed against structural performance requirements before its adoption in concrete production.

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Author Contributions

David Olaleye: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing – Original Draft. Olutosin P. Akintunde: Supervision, Resources, Writing – Review & Editing, Validation. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The raw experimental data (load-deflection curves, compressive strength test records, slump test records) are stored at the Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria.

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