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Investigating the Impact of Used Engine Oil on the Compressive Strength of Concrete with Varying Water-to-Cement Ratios

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

ABSTRACT

Concrete functions as primary construction materials even though its manufacturing process generates substantial environmental damage. Used Engine Oil (UEO) represents a dangerous hazard to the environment when waste management procedures fail to handle it properly. The research investigates the possibility of using UEO as a concrete admixture to boost sustainability by evaluating its effects on workability and mechanical properties at different Water-to-Cement (W/C) ratios. An experimental approach was employed, incorporating UEO at dosages of 0.15%, 0.30%, 1.0%, 3.0%, 15.0%, and 30.0% by cement weight. The production of concrete cubes and prisms allowed researchers to evaluate their mechanical properties in addition to slump tests for workability assessment at both 7-day and 28-day intervals. The evaluation shows that Used Engine Oil increases workability because slump values directly correlate with increasing UEO content. The evaluation reveals that elevated quantities of Used Engine Oil cause both compressive and flexural strength reductions because its heavy metals interfere with cement hydration processes. The research demonstrates that an optimal UEO range exists between 0.15%-0.30% dosage because this level provides better workability without substantial reductions in material strength. The findings demonstrate that lower W/C ratios help preserve material strength thus showing the need for careful mix design optimization. The

study recommends the use of UEO-modified concrete in non-structural applications and calls for further research on long-term durability and environmental impacts. The evidence supports Used Engine Oil as a sustainable construction material for waste management because it provides an effective solution to decrease our dependence on synthetic admixtures.

Keywords: Used Engine Oil, Compressive Strength, Water-to-Cement Ratio, Concrete Admixture, and Sustainability.

INTRODUCTION

Concrete remains one of the most relevant building materials employed in recent times because of its extraordinary strength, malleability, and robustness. It appears it has a significant effect in automation and urbanization, and it is the fulcrum of infrastructural advancement. Concrete's adaptability makes it the chosen material for an extensive range of structural projects, encompassing highways, dams, bridges, and skyscrapers (Acharya, 2024).

Despite the broader usage of concrete, there appear to be some challenges in making it, particularly as it pertains to environmental sustainability: for instance, a projected 8% of the world's annual carbon dioxide releases come from the intensive manufacture of cement, a central constituent of concrete (Adesina, 2020). There have also been intentional efforts to give sustainable practices agent attention as the construction industry grows to reduce the environmental effects of the manufacture of cement. Some of these actions include the combination of castoff materials and by products in concretes (Luhar, et al. 2019).

Recent studies have also looked into the environmental effects of Used Engine Oil (UEO), a by-product of automobile maintenance and industrial machinery on soil and water if not properly disposed. It is estimated that a single quart of UEO could contaminate 250,000 gallons of water (Loganathan & Kizhakedathil, 2023). Thus, researchers have proposed the usage of UEO for the purpose of concrete production as an admixture to increase workability and consistency as a waste management strategy (Keskin et al., 2019). This study seeks to analyse the effects of the usage UEO in concrete production to ascertain the compressive strength, workability, and general efficiency with different Water-to-Ratio (W/C). Thus, it seeks to use UEO's potential sustainable additive to understand the significant ecological problem and advance the formation of greener building systems.

Problem Statement

The improper disposal of UEO, by-product of internal combustion engine appears to pose critical ecological challenges that need immediate redress. The world-wide emission of UEO yearly, and the improper and unlawful disposal and mismanagement of it in the environment has caused long term environmental damage, polluting the soil and water, caused long-term ecological harm by contaminating soil and water systems, with heavy metals like lead, zinc, and chromium. Simonovic and Breach (2020) indicated that one litre of UEO could pollute million litres of fresh water. Thus, UEO poses domestic, industrial, and agricultural threat regardless of the efforts to manage waste disposal (Rony et al., 2024).

It appears the reusage of UEO as addictive in concrete production to efficiently manage waste and enhance sustainable building practices is being suggested by some studies; however, little is known in the features of its tensile and compressive strength. For example, some scholars have suggested that higher amounts of UEO may have detrimental effects on the mechanical properties of fresh concrete; other scholars suggest UEO could improve the workability of concrete (Qasrawi, 2024). There is also the need to fully understand how the different W/C ratio interacts with distinct UEO quantities to ensure performance and preserve structural integrity. Conducting a study to examine and close these gaps are essential to promoting the sustainability of the usage of UEO at various W/C ratios in construction for building durability, ecological safety, and effective waste management.

Research Objective

To assess the outcome of diverse UEO amounts on the compressive strength of concrete under different W/C ratios.

1. To regulate the ideal UEO quantity that maximizes workability while sustaining adequate structural performance.
2. To examine the interface between UEO amounts and W/C ratios and its impact on freshy and hardened concrete properties.

2. METHODOLOGY, PROCEDURE, AND MATERIALS

The research used experimental design, with concentration of Used Engine Oil being the independent variable, compressive strength of concrete being the dependent variable, and Water-to-cement ratios, types of cement, curing conditions, and testing equipment being the controlled variable. The ethical consideration measured and guidelines ensured that research related to the use of the materials and experimental procedure.

Materials

To safeguard the correctness of the experiment results, the materials used in this study were prudently selected (Used Engine Oil – UEO, cement, aggregates, and water. The chief binder in the concrete mix was Ordinary Porland Cement (OPC). With a strength grade and specification of 42.5N and BS EN 197:2000 for CEM I cement types. The cement mixed with water forms a hardened matrix that sustains the aggregate in place in the concrete production. The grade specification was selected to ensure quality performance for robustness and compressive strength.

Aggregates were separated into fine and coarse.

a. **Fine Aggregates:** This natural river sand with a high particle size of 4.75 mm was preferable; juxtaposed clay, silt, and organic matter that does not form a strong concrete bond. Thus, the river sand was cleaned after locally sourced. It was observed that it had a precise gravity of 2.66 and fineness modulus of 2.0.
b. **Coarse Aggregates:** This was comprised of crumpled granite from a close quarry. The aggregate size for concrete application ranged 16 mm and 20 mm, with specific gravity of 2.7 and satisfied BS 812:

Part 102. This requirement could safeguard satisfactory bonding, load-bearing ability, workability, strength, and durability when fine and coarse aggregates are combined.

Clean water, quality standard of BS EN 1008:2002, devoid of pollutants like organic matter, silt, harmful chemicals were used for mixing and curing. Water is a significant component of concrete manufacture, since it advances workability and fastens the hydration response of cement. It was expected that the quality of the concrete high ensuring strength and durability. The Ordinary Portland Cement (OPC) Grade 42.5N, BS EN 197:2000 was employed as the primary binder to achieve the robustness and compressive strength of the concrete. The fine aggregates were natural river sand with maximum particle size of 4.75 mm, specific gravity of 2.66 and fineness modulus of 2.0; the sand used in this study was cleaned and dried to remove impurities. The coarse aggregates were crushed granite with size distribution of 16 mm to 20 mm, specific gravity of 2.7 and met the requirement of BS 812: Part 102 for durability and load carrying capacity. Water used for mixing was clean water, complying with BS EN 1008:2002 for hydration and to improve workability. Sinking engine oil UEO was obtained from engineering workshops, being filtered to remove contaminants and added at cement weight ratios of 0.0%, 0.15%, 0.30%, 1.0%, 3.0%, 15.0%, and 30.0%.

Experimental Design

Under the direction of the study, UEO influenced workability, compressive strength, and flexural strength at different W/C ratios (0.40, 0.45, 0.50, and 0.55) under standard conditions. The proportion of cement, sand and coarse aggregate was cement: sand: coarse aggregate = 1:1.5:3 which is in conformity with mechanical concrete production standards. The concrete cube was prepared in the laboratory by pouring 150 mm × 150 mm × 150 mm cubes, tamping each layer 25 times to remove air bubbles and demolding the cubes after 24 hours and then curing them in water for 7 and 28 days. The compressive strength tests were performed with the help of compression machine. In the same way, 100 mm × 100 mm × 500 mm prisms were produced in three layers, tamped and cured for 28 days before being subjected to flexural strength test using three-point loading configuration.

Testing Procedure and Schedule

In this paper, workability of concrete was assessed by slump test (ASTM C143). A slump cone, tamping rod, base plate, and slump value in millimetres after pouring and tamping the concrete in three layers were used. The compressive strength test (BS EN 12390-3) included curing cubes, placed on the surface dried before being put in a compression testing machine where they were loaded to failure, and then the compressive strength was calculated. The flexural strength test was done using a flexural testing machine with three-point loading arrangement as per ASTM C78. The prisms were placed horizontally on supports 400 mm apart and an incremental load was applied on the prisms until failure. The flexural strength was calculated by the following formula: $(3PL)/ (2bd^2)$ where P is the failure load; L is the span length; b is the width; and d is the depth.

Day 1 saw the creation of specimens followed by their demoulding. On Day 7, slump tests were performed and the first compressive strength tests were executed. The final compressive strength and flexural

strength tests were performed on Day 28. The systematic approach provided a thorough analysis of the impacts of UEO and W/C ratios on concrete properties

3.0. RESULTS AND DISCUSSIONS

Cubes – Control Specimen

Table 1: *Compressive Strength of concrete cubes (control specimen) using w/c of 0.4*

Specimen ID	Cube size	Compressive Strength (N/mm2)	Average Compressive Strength
CNTRL 01	150x150x150	31.22	33.78
CNTRL 02		35.54	
CNTRL 03		34.58	

Table 1 shows the compressive strength of 150x150x150 concrete cubes for the experiment was determined at 28 days using the immersion method of curing to estimate the compressive strength of concrete with a water cement ratio of 0.4. The compressive strength 33.78 was determined by calculating the maximum crushing load per unit area.

Cubes - Used Engine Oil Specimen

Table 2: *Compressive strength of concrete cubes (used engine oil) using w/c of 0.4*

Used Engine Oil (%) Specimen ID	**Cube size**	**Compressive Strength [N/mm2]**	**Average Compressive Strength**
UEO 30.00	150x150x150	12.81	12.81
		11.43	
		14.19	
UEO 15.00	150x150x150	15.20	15.20
		16.22	
		14.80	
UEO 3.00	150x150x150	21.81	21.81
		22.68	
		20.94	
1.00	150x150x150	23.56	23.91
		24.02	

		24.15	
0.30	150x150x150	28.44	28.44
		27.88	
		29.0	
0.15	150x150x150	26.12	26.12
		25.97	
		26.27	

Table 2 displays the compressive strength of concrete cubes for various percentages of used engine oil specimens. Engine oil with percentages of 30%, 15%, 3%, 1%, 0.3%, and 0.15% was utilized here. The compressive strength of 150x150x150 concrete cubes for the experiment was determined at 28 days using the immersion method of curing to estimate the compressive strength of concrete with a water cement ratio of 0.4. The compressive strength was determined by calculating the maximum crushing load per unit area.

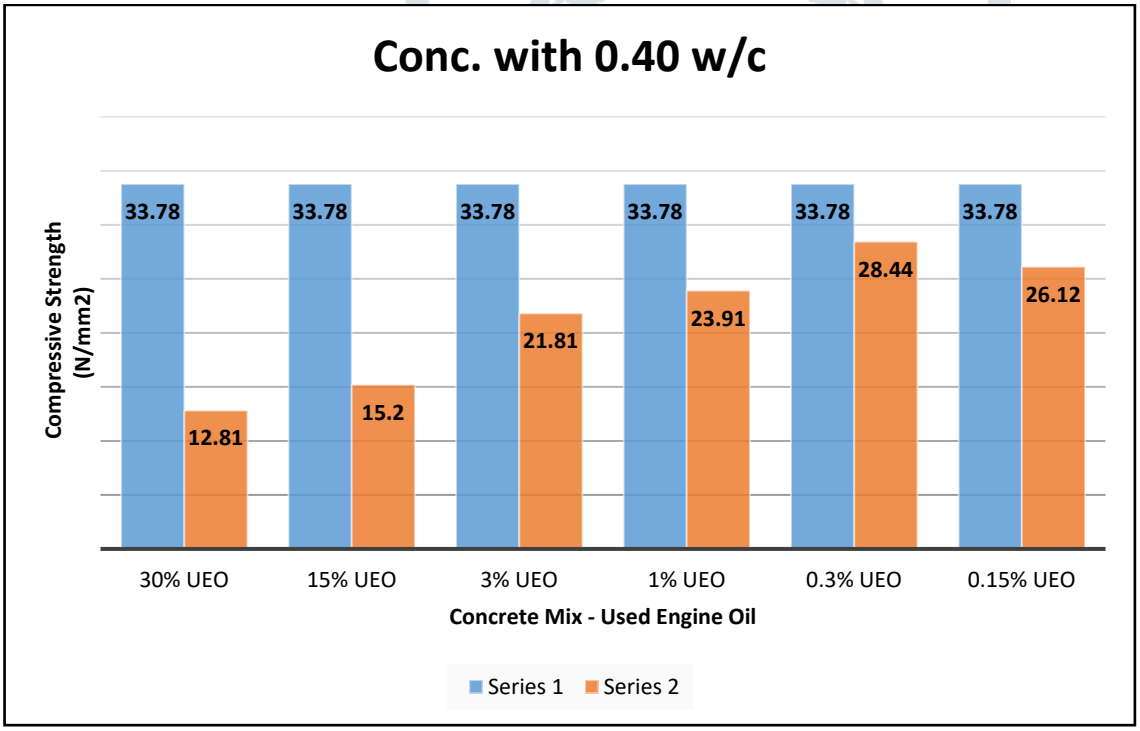

Figure 1: *Concrete with 0.4 w/c*

Figure 1 shows a 28-day compressive strength concrete incorporated with various dosages of UEO (30, 15, 3, 1, 0.3, and 0.15), % by cement mass. As seemed from the results reported in Fig. 1.0 that inducing of UEO into the concrete sample could slightly decrease the 28-day compressive strength. The amount of compressive strength decrease reaches about 15.8% and 22.68%, when a dosage of 0.30 and 0.15% UEO was utilized, respectively, compared with that of control specimen. Again, there was a drastic decrease in the 28-day concrete compressive strength as the decrease reached 62.08%, 55.0%, 35.44% and 29.22%, when the

dosage of 30.0, 15.0, 3.0 and 1.0 % Used engine oil (UEO) was utilized, respectively, compared with that of control specimen. The presence of Zinc element presents in the used engine oil and as an admixture retards hydration process which affects the mechanical properties of concrete.

This quiescently decreases the compressive strength of the concrete with increased dosage of used engine oil. Thus, the used engine oil functions as a chemical plasticizer akin to superplasticizer, improving workability more than control sample. According to the results of the slump test, the used engine oil acts as a lubricant to make the concrete more workable.

Compressive Strength of Cubes of Different W/C Ratio (0.45, 0.50 & 0.55)

Table 3 *Compressive Strength of concrete cubes using w/c of 0.45, 0.50 and 0.55*

	Compressive strength of Concrete N/mm2	
Specimen ID	Cube size	28days
Control	150x150x150	26.67
0.30% - UEO	150x150x150	30.32
0.15% - UEO	150x150x150	29.36
	Compressive strength of Concrete N/mm2	
Specimen ID	Cube size	28days
Control	150x150x150	26.67
0.30% - UEO	150x150x150	30.32
0.15% - UEO	150x150x150	29.36
	Compressive strength of Concrete N/mm2	
Specimen ID	Cube size	28days
Control	150x150x150	20.29
0.30% - UEO	150x150x150	21.46
0.15% - UEO	150x150x150	19.90

Table 3 shows the compressive strength of 150x150x150 concrete cubes for the experiment was assessed at 28 days using the immersion method of curing to determine the compressive strength of concrete

with water cement ratio of 0.45, 0.50 & 0.55 for 0.30% and 0.15% dosage of used engine oi

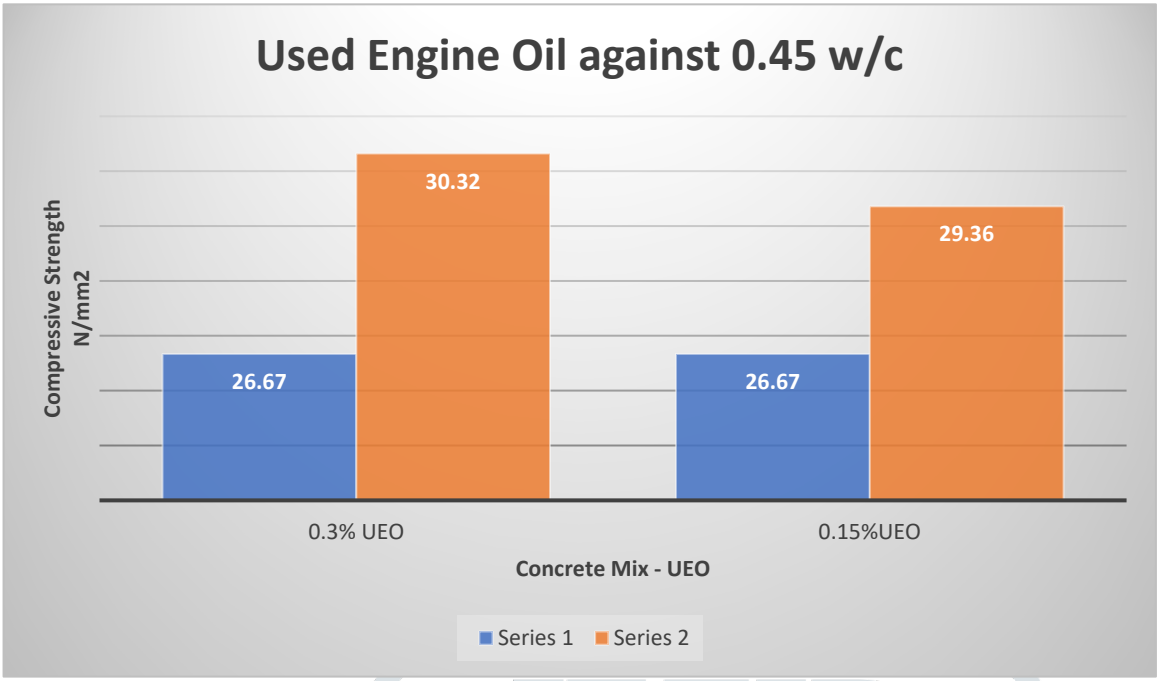

Figure 2: Used Engine Oil with 0.45 w/c

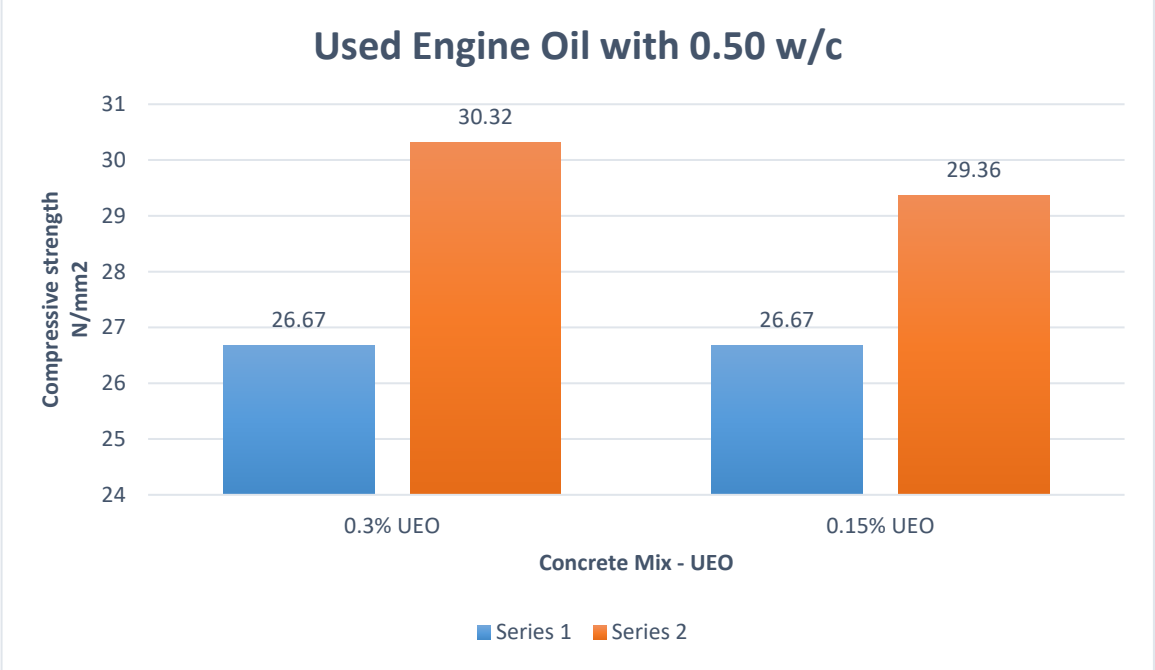

Figure 3. Used Engine Oil with 0.50w/c

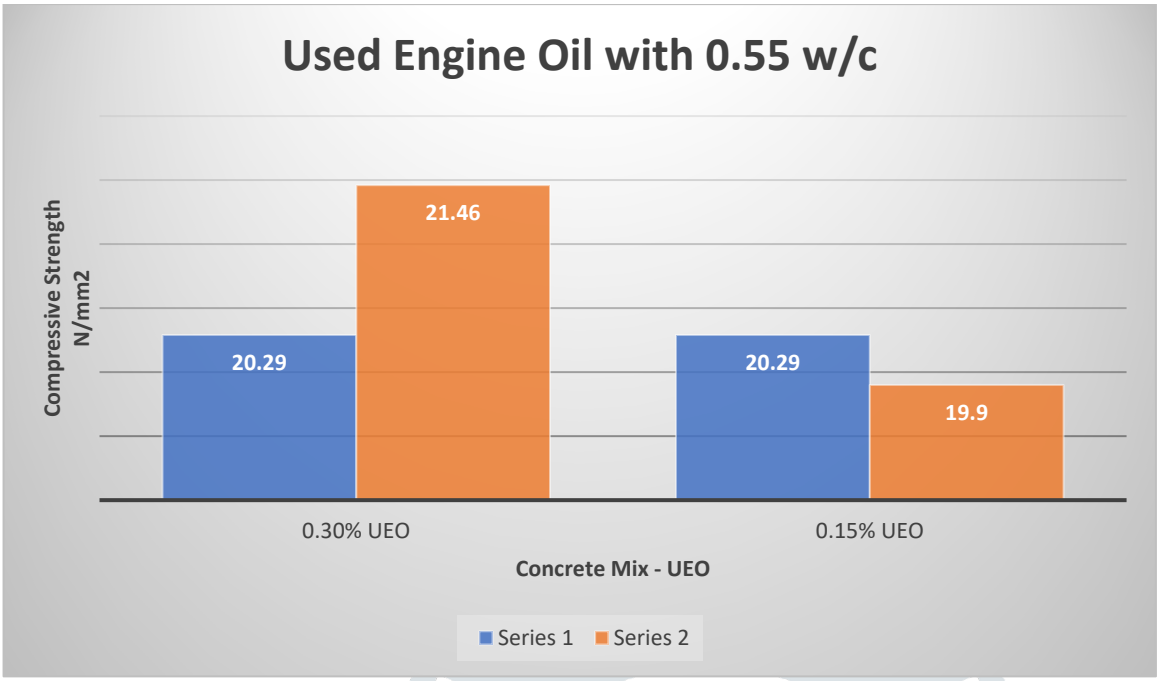

Figure 4. Used Engine Oil with 0.55 w/c

Slump Test Values (mm)

Table 4: *Slump values of concrete with UEO and 0.4 w/c*

Concrete mix ratio- 1: 1.5 :3 **Water Cement ratio (w/c) – 0.40**	
USED ENGINE OIL (UEO) %	**SLUMP (mm)**
Control	True slump
30.00	145.00
15.00	105.00
3.00	75.00
1.00	50.00
0.15	25.00
0.30	25.00

Table 4 shows the higher the dosage of the used engine oil with constant water cement ratio, the higher its slump value. This clearly shows 30.0% dosage of used engine oil has a higher slump value as compared to that of 0.30% and 0.15% with the lowest slump values of used engine oil, with constant water cement ratio.

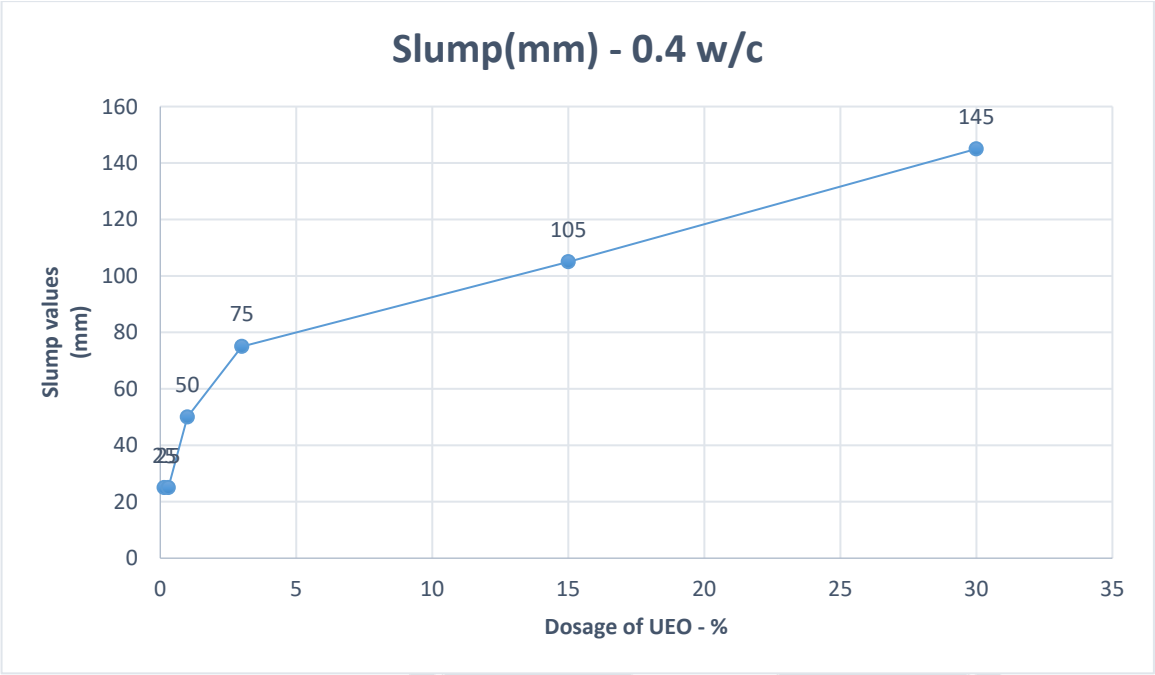

Figure 5. Slump values chart

Table 5: ***Slump Test Values (mm) for W/C: 0.45, 0.50 and 0.55***

USED ENGINE OIL - UEO (%)	**Concrete Mix ratio (1: 1.5: 3)** WATER CEMT RATIO	SLUMP VALUE (mm)
0.30%		50.0
0.15%	0.45	40.0
Control		5.0
0.30%		100.0
0.15%	0.50	75.0
Control		15.0
0.30%	0.55	150.0
0.15%		120.0
Control		30.0

Table 5 shows the effect of inducing used engine oil (UEO) into OPC mixes, as an admixture, on their initial slump. The higher the dosage of the used engine oil with constant water cement ratio, the higher its slump value. This clearly shows 0.3% dosage of used engine oil has a higher slump value as compared to that of 0.15% of use engine oil with constant water cement ratio. The slump of a concrete prism with 0.50 water cement ratio and 0.3% and 0.15% of used engine oil (UEO). It was deduced that the higher the dosage of the used engine oil with constant water cement ratio, the higher its slump value. This clearly shows 0.3% dosage of used engine oil has a higher slump value as compared to that of 0.15% of use engine oil with constant water cement ratio. Also, the slump of a concrete prism with 0.55 water cement ratio and 0.3% and 0.15% of used engine oil (UEO). It was deduced that the higher the dosage of the used engine oil with constant water cement ratio, the higher its slump value. This clearly shows 0.3% dosage of used engine oil has a higher slump value as compared to that of 0.15% of use engine oil with constant water cement ratio.

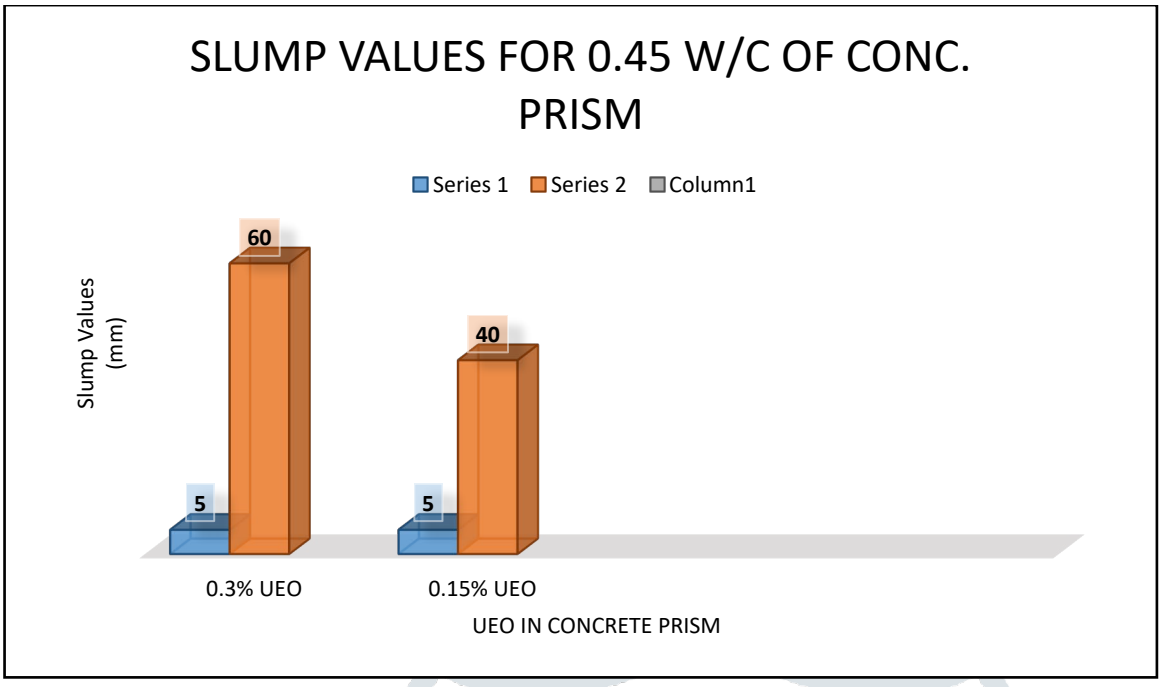

Figure 6. showing the slump of a concrete prism with 0.45 water cement ratio and 0.3% and 0.15% of used engine oil (UEO).

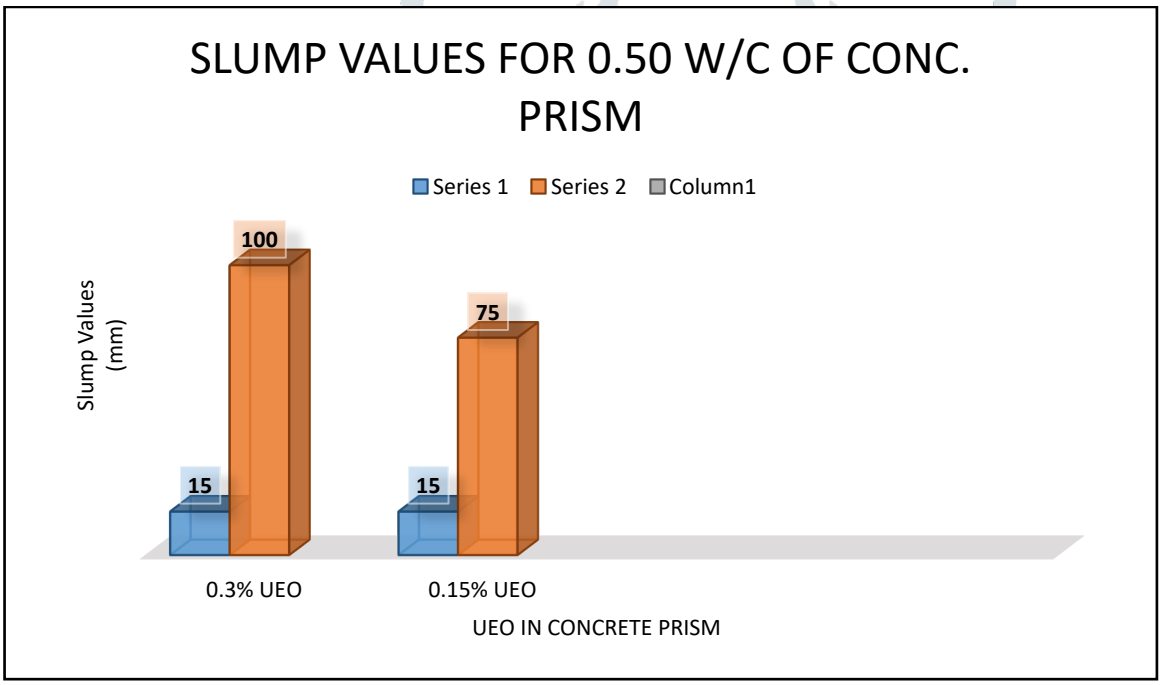

Figure 7. Showing the slump of a concrete prism with 0.50 water cement ratio and 0.3% and 0.15% of used engine oil (UEO).

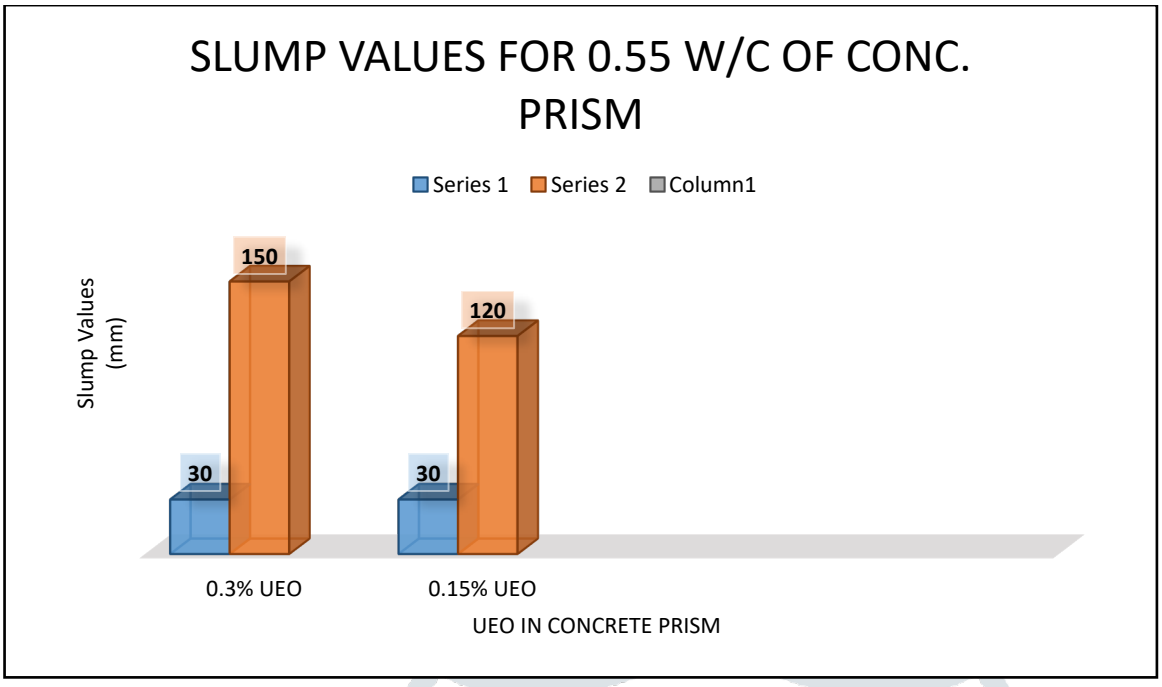

Figure 8 Showing the slump of a concrete prism with 0.55 water cement ratio and 0.3% and 0.15% of used engine oil (UEO).

Flexure – Tensile Strength of Prism with UEO

Table 6: *Tensile Strength of Prism with UEO*

	Specimen	Beam Size	28th Day Tensile Strength of Prism (N/mmm2)
UEO (%)	Control	100x100x500	6.50
	30.0%		3.24
	15.0%		3.99
	3.0%		4.21
	1.0%		4.50
	0.3%		5.49
	0.15%		5.75

Table 6 shows used Engine Oil of 30%, 15%, 3%, 1%, 0.3% & 0.15% was used here. The Flexural strength of 100x100x500 concrete prisms for the experiment was assessed at 28 days using the immersion method of curing to determine the flexural strength of concrete prism with water cement ratio of 0.4. The Flexural strength was computed as the maximum crushing load per unit area. The table show the flexural strength the of concrete prism for the various percentage of used engine oil specimens.

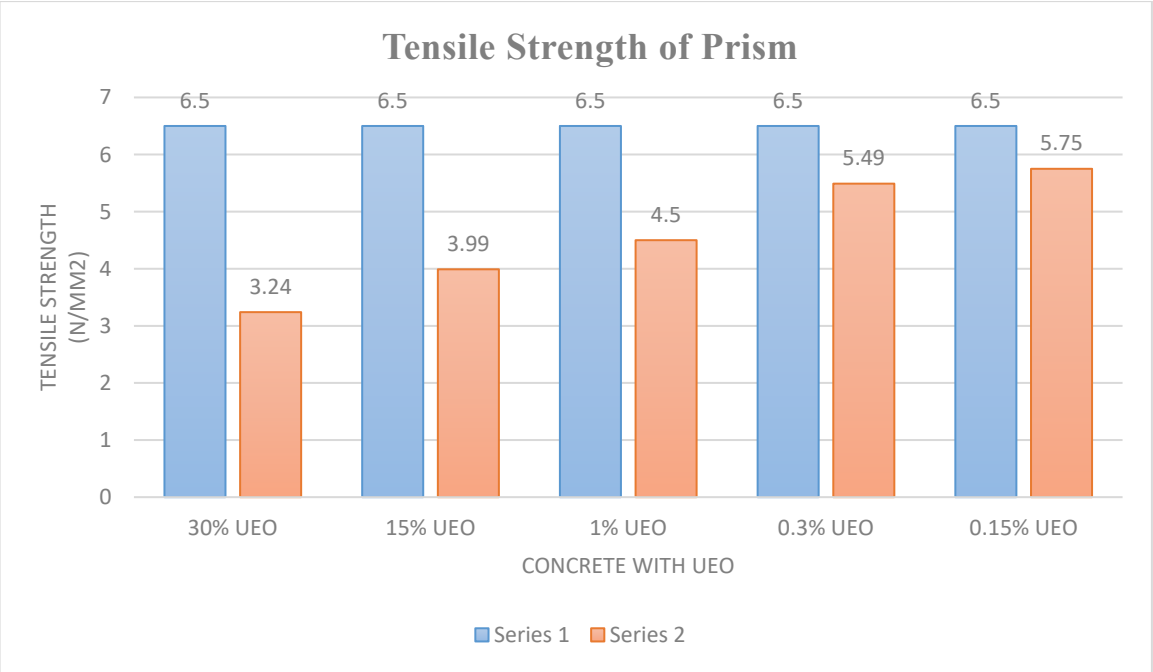

Figure 9. Tensile Strength of Prism with their Control and UEO

Comparison with Literature Findings

The results are in agreement with the findings of previous studies that have been conducted on the use of UEO in concrete. Most of the studies that have been conducted have indicated that the use of UEO in concrete mixes enhances workability. For example, Shafiq et al. (2011) noted that the incorporation of UEO increased the slump of concrete by 18-38%. In the same vein, Hamad et al. (2003) established that UEO is a plasticizer and hence increases the slump and air content of fresh concrete mixes. These observations are in agreement with the present study, which showed that slump values were higher at higher UEO additions. The effect of UEO on compressive strength has been among the most important topics in several research studies. Hamad et al. concluded that UEO increased workability of concrete while not affecting its compressive strength.

On the other hand, Shafiq et al. (2011) reported that UEO increased workability but at the cost of slightly lower compressive strength at higher additions. The present research also found an optimal range of UEO addition (0.15%-0.30%) that improved workability without significantly compromising on strength. Abdelaziz et al. (2010) investigated microstructural consequences of UEO in concrete and observed minor decreases in 28-day compressive strength, homogeneity and density, as well as increased porosity and water inflow rates. These microstructural changes are in agreement with the present study which shows that elevated UEO additions may hinder cement hydration due to heavy metals present in UEO, thereby decreasing the compressive strength. The benefits of using UEO in concrete have been reported in different studies as regarding the environmental aspect. Using UEO as an admixture does not only solve the problem of disposal but also helps in reducing the environmental impact of construction. This study also agrees with these findings and also adds that the use of UEO has the dual advantage of improving workability of concrete as well as being environmentally friendly.

As pointed out by Chin et al. (2007), this study also shows that high UEO additions result in severe reductions in compressive and tensile strengths. The negative effects are as a result of the slow hydration of the cement that is caused by the presence of heavy metals in UEO, particularly zinc. As indicated by Kamal et al. (2014), it is very important not to exceed UEO dosage below 0.50% to optimize workability with minimal impact on strength. These findings are in agreement with the range of the present study, which is 0.15-0.30 percent.

4.0. RECOMMENDATIONS

1. Optimize UEO dosages between 0.15%-0.30% to balance strength and workability. Explore how UEO impacts long-term compressive strength in further research.
2. Apply UEO to construction tasks where high workability is needed but structural strength is not the primary concern. Create standardized construction guidelines for UEO admixture proportions.
3. Study how UEO affects modified concrete with varying water-to-cement ratios across different curing methods.
4. Analyze how UEO works with supplementary cementitious materials like fly ash and silica fume together.

4.1. CONCLUSION

The research aim was to establish the impact of Used Engine Oil on compressive strength and workability of concrete with different Water-to-Cement ratio. The results of the study also show that UEO increases workability by increasing the slump values but reduces the compressive and flexural strength at higher dosages. It was also established that an optimal addition of 0.15% to 0.30% UEO by weight of cement is effective in enhancing workability with only slight reduction in strength.The results of the study can be used to suggest the application of UEO as a sustainable admixture for non-structural purposes to minimize the risks posed by its incorrect dumping. Nevertheless, attention should be paid to the strength and service life of the concrete. Further work should be directed towards the evaluation of the long-term properties, environmental consequences and fire performance of the concrete modified with used engine oil for its effectiveness in sustainable construction practices.

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