EXPERIMENTAL INVESTIGATION ON THE PROPERTIES OF FRESH AND HARDENED CONCRETE WITH USED ENGINE OIL AS SUPER PLASTICIZER

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Abstract - *The modern construction practice includes using industrial wastes or by-products as raw materials in cement and concrete. These impart many benefits to the environment and bring about an economic impact because the cost of waste disposal is constantly increasing due to strict environmental regulations. Excellent flowability is one of the important characteristics of concrete for easier handling and placing and it facilitates the removal of undesirable air voids by introducing super-plasticizer (SP). With the increase usage of concrete, new type of admixtures that are cost effective may have many economic and technical impacts on the construction industry as well as worldwide concrete usage. In the meantime, the number of vehicles is increasing all over the world and this leads to the increase production of used engine oil (UEO). It was found that addition of UEO to concrete was similar to adding air entraining admixture to concrete.*
The percentage addition of UEO in concrete was varied as 0.15, 0.3, 0.5, 0.8 and 1% of weight of cement. In-order to study the effect of UEO in concrete, slump test, compaction factor test, compressive strength and split tensile strength test were conducted. The optimum percentage of addition of UEO to concrete was found. The flexural strength, load deflection behaviour, crack pattern, crack width, and ductility factor were studied on slender beams with shear span by depth ratio 2.7, subjected to two point loading. The OPC beam with SP (control beam) was compared to the OPC beam with UEO. Test results show that the optimum addition of UEO to concrete is 0.3% of weight of cement. The compressive strength increased by 5-8% for UEO added concrete when compared to SP added concrete. The slump value for optimum addition of UEO to concrete was 74 mm. The split tensile strength showed a 5% increase in UEO added concrete than in SP added concrete. The load carrying capacity of UEO added OPC beam increased by 19 -25% compared to OPC beam with SP. The crack patterns were similar and the crack width reduced by 0.01mm for UEO added OPC beam compared to SP added OPC beam. The ductility factor increased by 5-6% for the OPC beam with UEO compared to the OPC beam with SP. Thus UEO is a good alternative for SP and thereby solving the problems of higher cost of SP and efficient utilization of hazardous waste like UEO which causes severe environmental issues.

Key Words: UEO-used engine oil, SP-super-plasticizer, OPC-ordinary portland cement

1. INTRODUCTION

Recently, the interest on utilization of greener technology is on the rise. A lot of wastes are being utilized to replace the commercially available materials. Wastes or better known as by-products obtained from the industrial, agricultural or any other process which has no economical demand has to be disposed of properly. Industrial wastes and by-products either solid or liquid based chemical are available in large quantities all over the world. Environmental agencies in most of the countries have laws and regulations regarding safe handling or disposal of the waste. However, huge amount of such waste are illegally disposed of, which may cause severe environmental problems. Some wastes can be used as chemical admixtures and additives, which can alter the fresh and hardened properties of concrete. Concrete industry has considered recycling industrial by-products to be used as concrete additives in order to produce higher quality and more sustainable construction material. Water reducers are maybe the most broadly utilized admixtures in the concrete industry, their utilization in ready-mixed concrete being especially common. The effect and results of using admixtures depend on the type of cement, brand of cement, aggregate grading, mix proportions and the richness of the mix. Sometimes the admixture affect more than one property of the concrete. Sometimes more than one admixture is used in the same mix and sometimes the admixture affect the desirable properties of the concrete adversely. Therefore the selection of admixtures should be done wisely.

Excellent flowability is one of the important characteristics of concrete for easier handling and placing and it facilitates the removal of undesirable air voids by introducing super-plasticizer (SP). Super-plasticizers are an improved version of plasticizers. The use of super-plasticizers reduce the water content to an extent up to 30 percent, without reducing workability. Super-plasticizers are added for the production of flowing, self-levelling, self-compacting tremie concreting and for the production of high strength and high performance concrete. Super-plasticizers are more powerful as dispersing agents and are high range water reducers. The use of super-plasticizer has made it possible to use water-cement ratio as low as 0.25 and yet to make workable concrete to obtain strength of the order 100Mpa or more. The addition of super-plasticizer produces a homogeneous, cohesive concrete generally without any tendency for segregation and bleeding. While the previous researchers have discussed the powerful function of superplasticizer, an alternative admixture to replace it is something new to be explored. With the increase usage of concrete, new type of admixtures that are cost effective may have many economic and technical impacts on the construction industry as well as worldwide concrete usage. However, production of super-plasticizer is commonly associated with the water pollution. Liquid and solid waste produced due to the manufacturing process discharged into public sewerage network was found violating the environmental regulations. The chemicals used during the manufacturing processes are also hazardous and have severe impact on the environment. In the meantime, the number of vehicles is increasing all over the world and this leads to the increase production of used engine oil (UEO). It is estimated 380 million gallons of used engine oil are recycled each year. It was reported that worldwide 45% of used engine oil is being collected while remaining 55% is thrown away the end used in the environment. Besides that, 40% of the total re-used oil is improperly disposed. Used engine oil poured into household drains or directly onto the ground, may leads into waterways and ground-waters and pollutes the fresh water.

The potential of used engine oil as concrete admixture were found by Mindess and Young. They were reported that the leakage of oil into the cement in older grinding units result in concrete with greater resistance to freezing and thawing. This implies that adding used engine oil to the fresh concrete mix could be similar to adding an air entraining chemical admixture, thus enhancing some durability properties of concrete while serving as another technique of disposing the oil waste. It was also discussed by Chin that used engine oil has similar super-plasticizer properties because of the SO_3 content.

This research paper was carried out to find a solution to the increasing concern about environmental issues from super-plasticizer (SP) production and used engine oil (UEO) disposal. The main objective of this research paper is to identify the effects of used engine oil with respect to strength, important consideration in the design and construction of new structures and also when assessing the condition of existing structures.

1.1 Research Significance

Used engine oil is a good alternative for super-plasticizer. It acts similar to an air entraining admixture when added to concrete. But there are not much investigations to prove it. This research study is done to support and prove that the used engine oil can be used as an alternative to super-plasticizer. Thus solving the problems of higher cost of super-plasticizer, leading to the efficient utilization of hazardous waste like used engine oil which causes severe environmental issues. Thus finding a solution for the increasing concern about environmental issues from super-plasticizer (SP) production and used engine oil (UEO) disposal.

2. LITERATUE REVIEW

S.C. Chin et.al (2012), have studied the effects of used engine oil as super-plasticizer in concrete and the failure mode was in shear. This was done according to British Standard in Civil Engineering Department, Universiti Teknologi PETRONAS, Malaysia. The water-cement ratio was 0.55. Ten RC beams were casted with 100% OPC concrete, 20% FA and 20% RHA blended cement concrete. 0.15% dosage of admixtures used engine oil, new engine oil, and superplasticizer for each cases and tested by four point loading. Load deflection behaviour and crack pattern were studied. OPC/RHA RC beams containing used engine oil and superplasticizer exhibit higher capacity, 18-26% than their corresponding control mix.

S. Beddu et.al (2016), Department of Civil Engineering, Universiti Tenaga Nasional, Malaysia; Department of Civil Engineering, Universiti Teknologi PETRONAS, Malaysia. They studied the effect of used engine oil in concrete as an admixture in concrete durability. This was done according to British Standard and Malaysian Standard. Here the water-binder ratio was 0.55. The addition of used engine oil to concrete was varied from 0.15 to 1 percentage of weight of cement. The super-plasticizer used was Sikamen N1. Porosity test, chloride penetration test and concrete with used engine oil as admixture subjected to high elevated temperature exposure was conducted. Results showed that the addition of used engine oil to concrete was similar to that of adding an air-entraining admixture. Concrete with used engine oil had improved workability and porosity decreased at 0.3% of weight of cement.

Mohammed Noori Hussein (2013), Civil Engineering Department, Iraq University College, has studied the properties of concrete containing used engine oil and new engine oil. Research was done according to Iraq Standard. Here the water cement ratio was varied as 0.54 and 0.48. The addition of used engine oil to concrete was 0.75% of weight of cement. The engine oil used was LIQUI-MOLY 10W-30. Use of both new and used engine oil gives lower but comparable compressive strength compared with the control sample and that because engine oil will effect on the bonding of the aggregate in the concrete. Concrete with used engine oil has better compressive strength compared to concrete with new engine oil because the viscosity of used engine oil is lower than the new engine oil.

Nasir Shafq et.al (2011), Department of Civil Engineering University Technology PETRONAS, 31750, Tronoh, Perak, Malaysia. Slump and air content and hardened concrete i.e. compressive strength, porosity and the coefficient of oxygen permeability. Concrete mixes were made of 100% cement (OPC) and OPC blended with fly ash, FA as partial replacement. The used engine oil dosage was kept 0.15% after various trial mixes. Properties of concrete containing used engine oil were compared with the properties of concrete containing new engine oil, commercially produced air entraining agent, super-plasticizer and the plain concrete. Here the water-cement ratio was 0.54 and the super-plasticizer used was SIKA AER 50/50. With the addition of used engine oil, concrete slump was increased by 18% to

38% and air content by 26% to 58% as compare to the slump of control concrete. Porosity and oxygen permeability of concrete containing used engine oil was also reduced and the compressive strength obtained was approximately same as that of the control mix.

Dr. Gamal Elsayed Abdelaziz (2009), Associate Professor, Faculty of Engineering in Shoubra, Benha University, Egypt, studied on the utilization of used engine oil in concrete as a chemical admixture. The performance of concrete containing used engine oil in its hardened state was then thoroughly studied, through assessing the various mechanical and microstructure-related properties, namely, 28 day-compressive strength, surface hardness, homogeneity, sorptivity, porosity and degree of hydration. Ten OPC concrete mixes and another ten OPC paste mixes made with different contents of UEO, water reducing admixture and air-entraining admixture (0, 0.15, 0.30 and 0.60%, by cement mass) were consequently prepared. Used engine oil decreases the initial setting time and increases the consistency, air content and rate of fluidity loss of OPC concrete. These effects increase with increasing the dosage of used engine oil in OPC mixes. However, the surface hardness of concrete has not adversely affected due to the use of used engine oil. The results also indicated that the fresh and hardened characteristics of OPC concretes containing either used engine oil or air entraining admixture are comparable.

3. RESEARCH OBJECTIVE

The objective of this research is to find a solution for the increasing concern about environmental issues from super-plasticizer (SP) production and used engine oil (UEO) disposal. Also, to support that used engine oil can be used as an alternative to superplasticizer in concrete. For this, the optimum addition of used engine oil to concrete is found out. The fresh and hardened properties of concrete with super-plasticizer is compared with the fresh and hardened properties of concrete with used engine oil. Flexural behaviour, load-deflection behaviour, crack pattern and crack width, and ductility factor of the RC beam with used engine oil is studied and compared with RC beam with super-plasticizer.

4. MATERIALS USED

CEMENT: Ordinary Portland Cement (OPC) of 53 grade was used. The properties of cement was found out.

SL.NO.	PROPERTY	RESULT
1.	Specific Gravity	3.25 (IS 4031-1988 part 11)
2.	Initial Setting Time	39 min (IS 4031-1988 part 5)
3.	Final Setting Time	5 hrs and 28 min (IS 4031-1988 part 5)
4.	Consistency	29% (IS 4031-1988 part 4)
5.	Fineness	9% (IS 4031-1988 part 1)
6.	Soundness	1mm (IS 4031-1988 part 3)
7.	Compressive Strength	26N/mm² - 3day (Part 6 of IS 12269-1987) 35N/mm² – 7day

FINE AGGREGATE: Locally available river sand which is free from organic impurities was used. The properties of fine aggregate was found out.

SL.NO.	PROPERTY	RESULT
1.	Specific Gravity	2.67 (M Sand IS 383-1970, IS 2316-1963)
2.	Sieve Analysis	Zone I (M Sand IS 383-1970, IS 2316-1963)
3.	Fineness Modulus	5.43 (M Sand IS 383-1970, IS 2316-1963)

COARSE AGGREGATE: Crushed angular granite metal from a local source was used as coarse aggregate. The properties of coarse aggregate was found out.

SL.NO.	PROPERTY	RESULT
1.	Specific Gravity	2.73
2.	Water Absorption	0.5%
3.	Bulk Density	1.5g/cm³
4.	Void Ratio	0.79
5.	Porosity	0.443
6.	Fineness Modulus	5.18

WATER: Clean water, which was free from all impurities was used for the entire work of concrete preparation and curing.
STEEL: The bottom and top reinforcements provided for the beams are 16 mm and 10 mm dia bars respectively. 8 mm dia stirrups were used. Fe 500 Grade steel is used.
USED ENGINE OIL: The used engine oil used in this research was obtained from a local service station at Nagampadom, Kottayam. The chemical composition of the used engine oil was found out. The specific gravity is 1.2.

SiO_2	0%
Fe_2O_3	0.43%
CaO	15.9%
SO_3	37%
P_2O_5	8.95%
ZnO	17.7%
Cl^-	15.9%

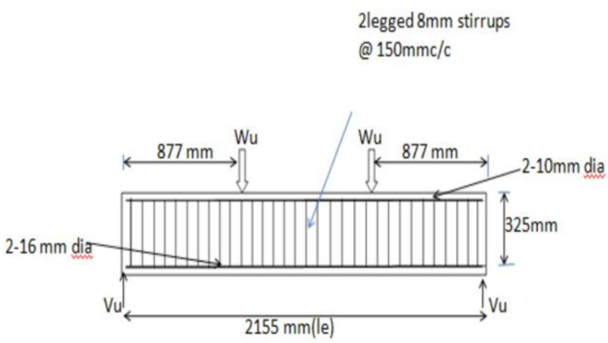
SUPER-PLASTICIZER: High range water reducer helps to disperse the cement particles in the mix and enhance the mobility and fluidity of the concrete mix. The super plasticizer used in this research is Naphthalene based CERAPLAST-300. The specific gravity is 1.2.

MIX PROPORTION: The mix used in this research study is M40. The mix design was carried out as per the specific code, IS 10262-2009.

PARTICULARS	QUANTITY (per m³ of concrete)
Cement	422.14 kg
Fine Aggregate	762.55 kg
Coarse Aggregate	1169.53 kg
Water	147.75 kg
Water-binder ratio	0.35 (by weight)
Density	2501.94 kg/m³
Mix Proportion (by weight)	1: 1.80: 2.77

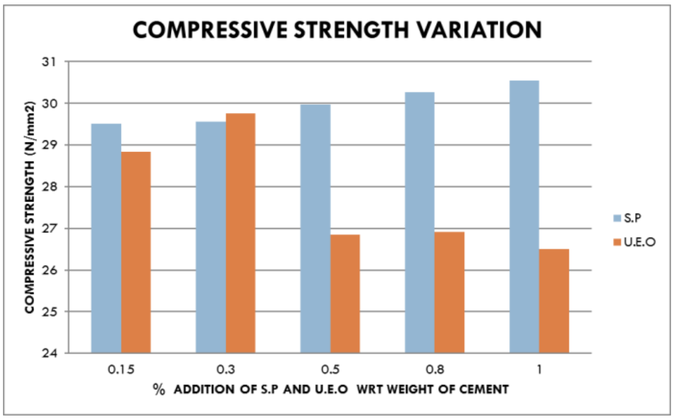
5. EXPERIMENT PROGRAM

The addition of used engine oil and super-plasticizer to concrete was varied as 0.15, 0.3, 0.5, 0.8 and 1% of weight of cement and compared. Three cubes of 150 mm side were cast for each varying dosage of super-plasticizer and used engine oil. Three cylinders of diameter 15 cm and height 30 cm were cast for each varying dosage of super-plasticizer and used engine oil. The compressive strength, slump value, split tensile strength and compacting factor for every dosage of used engine oil and super-plasticizer to concrete was compared and studied. After finding out the optimum dosage of used engine oil to concrete, beams were cast to compare and study the flexural behaviour, load deflection behaviour, crack width, crack pattern and ductility factor of RC beams with used engine oil as super-plasticizer and CERAPLAST-300 as super-plasticizer. Slender beam having shear span to effective depth ratio 2.7 (a/d = 2.7) was considered. Beams with 150 mm x 355 mm cross-section and 2155 mm effective length were cast and simply supported and subjected to two point loading. Beams are designed for flexural failure. Steel stirrups of 8 mm diameter were used at 150 mm spacing along the beam length for all beams. The top and bottom steel reinforcements were 10 mm and 16 mm diameter respectively.

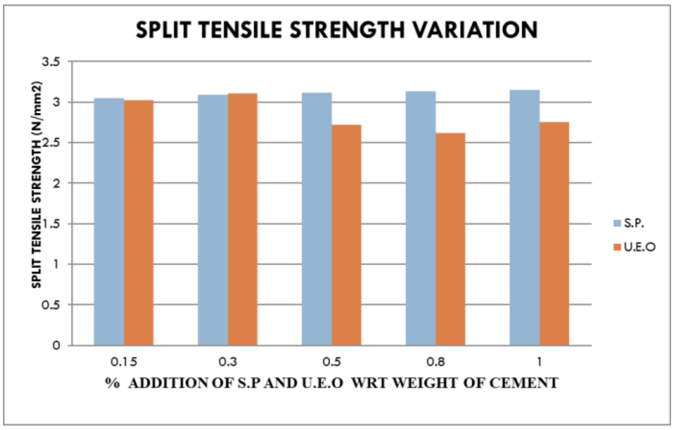


In order to study the characteristics of concrete, the following test were done: Compressive strength test, Split tensile strength test, Slump test and Compaction factor test.

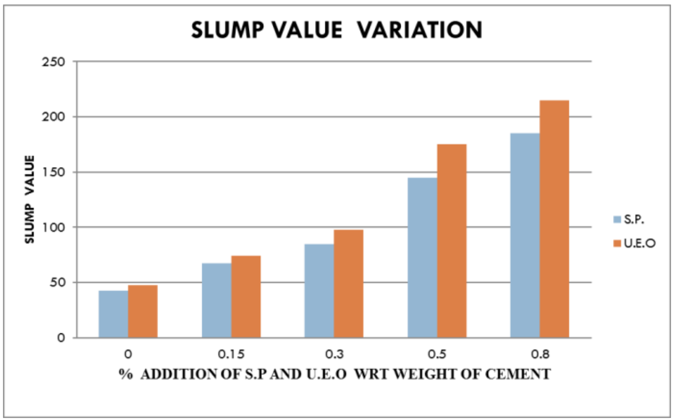
5. RESULTS AND DISCUSSIONS



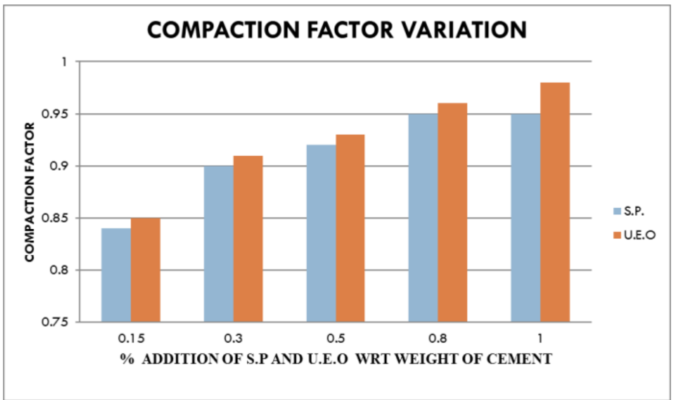
It can be seen from the graph that there is a steady increase in compressive strength when the dosage of super-plasticizer is increased. But in the case of used engine oil addition, there is a steady increase in compressive strength from 0.15 to 0.3% addition, about 3% increase in compressive strength. But as the dosage of used engine oil to concrete is increased from 0.5 to 1%, there is a drastic decrease in compressive strength. This is due to the heavy metals present in the used engine oil, namely ZnO and P_2O_5. They become active when the addition of used engine oil to concrete is increased from 0.5 to 1 percentage. ZnO and P_2O_5 reduce the rate of hardening of concrete by affecting the C-S-H gel. Thus decreasing the strength development of concrete.



It can be seen from the graph that there is a steady increase in split tensile strength when the dosage of super-plasticizer is increased. But in the case of used engine oil addition, there is a steady increase in split tensile strength from 0.15 to 0.3% addition, about 2.8% increase in split tensile strength. But as the dosage of used engine oil to concrete is increased from 0.5 to 1%, there is a notable decrease in split tensile strength. This is due to the heavy metals present in the used engine oil, namely ZnO and P_2O_5.



Slump value increased from 22.5 mm to 42.5 mm when dosage of super-plasticizer was increase by 0.15%. A steady increase in the slump value was observed when the super-plasticizer dosage was increased to 0.3% and 0.5%, which was measured as 67.5 mm and 85 mm. There was a sudden jump in the slump value to 145 mm when the super-plasticizer dosage was increased to 0.8%. However at 1% super-plasticizer dosage, the rate of increment was lower and it reached to 185 mm. It can be observed that when dosage of 0.15%, 0.3% and 0.5% were used, the slump value of UEO mixes were quite close to that of SP mixes. For example for 0.15% dosage of used engine oil mix showed a slump value of 47.5 mm as compared to the corresponding super-plasticizer mix that showed a slump value of 42.5 mm. However, the gap widened when a dosage of 0.8% and 1% UEO were added. At 0.8% dosage, used engine oil mix resulted in 175 mm slump as compared to 145 mm slump value of the super-plasticizer mix. Similarly, when 1% dosage of used engine oil was added the slump value of 215 mm was measured, whereas with 1% super-plasticizer dosage the slump of 185 mm was observed.



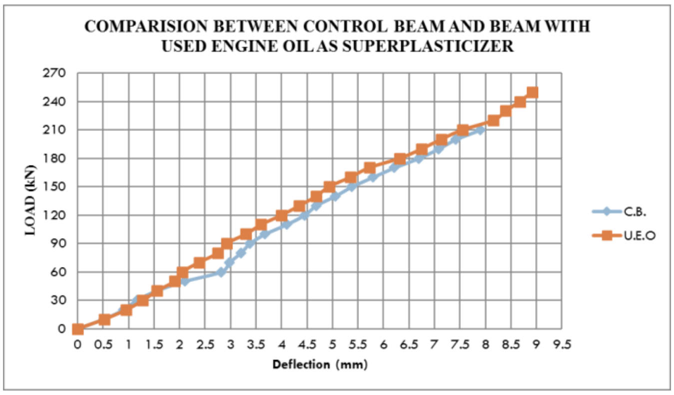
Concrete with super-plasticizer showed increase in compacting factor with increase in dosage. Concrete with used engine oil showed a steady increase in compacting factor with increase in dosage. Considering the compressive strength, split tensile strength, and slump value of the varying dosage of used engine oil to concrete, 0.3% of addition by weight of cement can be taken as the optimum percentage addition of used engine oil to concrete.

FIRST CRACK LOAD AND ULTIMATE LOAD

Sl. no.	Beam	First crack load	% increase	Ultimate load	% increase	Failure mode
1.	Control Beam - CB	120 kN	25%	210 kN	19%	Flexure failure
2.	Beam with UEO	150 kN		250 kN		Flexure failure

CRACK WIDTH

Sl.no.	Beam	First crack width	% variation	Ultimate load crack width	% variation
1.	Control Beam - CB	0.02mm	0%	0.05	20%
2.	Beam with UEO	0.02mm		0.04	



The ultimate load carrying capacity of the OPC beam with used engine oil increased by 19 -25% when compared to the OPC beam with super-plasticizer. For the beam with used engine oil, the deflection at yield point is 3 mm at a load of 90 kN and for the beam with super-plasticizer, the deflection at yield point is 2.8 mm at a load of 60 kN.

DUCTILITY FACTOR

Sl. No.	Beam	Ultimate deflection	Deflection at yield point	Ductility ratio	% increase
1.	Control Beam - CB	7.9mm	2.8mm	2.82	5.31%
2.	Beam with UEO	8.92mm	3mm	2.97	

Ductility is defined as the ability of a material to withstand large in-elastic deformations without fracture. The ductility factor for the OPC beam with super-plasticizer is 2.82 and the ductility factor of OPC beam with used engine oil is 2.97. The ductility factor increased by 5-6% for beam with used engine oil when compared to beam with super-plasticizer.

6. CONCLUSIONS

- The optimum addition of UEO to concrete was found to be 0.3% of weight of cement.
- OPC concrete beams that contained optimum amount of UEO showed greater load carrying capacity than the OPC beam with same amount of SP. It was 19 to 25% than the corresponding control mix.
- The effect of used engine oil on the cracking pattern were observed similar to that of super-plasticizer, but the crack width reduced by 0.01mm and the failure mode was in flexure.
- A steady increase in the slump value was observed when the UEO dosage was increased to 0.15% and 0.3% and was good compared to concrete with SP. There was a sudden jump in the slump value to 170 mm and 200 mm when the UEO dosage was increased to 0.8% and 1%.
- UEO has the potential to improve concrete strength as water reducing admixture same as SP. There was an increase in compressive strength from 0.15 to 0.3 % of UEO added to concrete. But further addition decreased the compressive strength. Compressive strength increased by 5-8% in UEO added concrete when compared to SP added concrete.
- In the concrete, engine oil will act as lubricant that makes the concrete more workable. However, concrete with SP have lower compacting factor compared to concrete with UEO.
- The first crack load capacity increased by 25 % for the OPC beam with UEO compared to the OPC beam with SP.
- The ultimate load capacity increased by 20 % for the OPC beam with UEO compared to the OPC beam with SP.
- The ductility ratio increased by 5-6% for the OPC beam with UEO compared to the OPC beam with SP.
- A good alternative to high cost SP and an efficient solution for the environmental issues from superplasticizer (SP) production and used engine oil (UEO) disposal.

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