Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 1 (2024)

Analyzing Performance of Used Insulation Oil as Admixture for Concrete

N. Suganya[*1], M. Anusha[2], S. DurgaNandhini[3]

[1 2 3] *Department of Civil Engineering, Sri Sairam Engineering College, West Tambaram, Chennai – 600044, India.*

Abstract:- Used Insulation Oil (UIO) is the black waste oil extracted after usage in transformer. This oil has no further usefulness and is disposed to land causing soil degradation. In our study, we examined how concrete behaves when adding UIO as admixture. For varied proportions of UIO i.e., 1%, 1.5% and 2% by weight of cement, properties like workability, Compressive Strength (at 3,7,14 and 28 days), Heat of Hydration, Water absorption and Flexural strength are comparatively studied with conventional M25 grade concrete. The results showed much reduced workability under increasing dosages but improved Flexural and Compressive strength at 1.5% dosage. On increasing dosage of oil, the fresh concrete became highly viscous and sticky thereby leading to poor workability. However, the hardened concrete showed better performance. Water absorption and heat of hydration were notably reduced under increasing dosages. Compressive and Flexural strength were increased at 1.5% dosage.

Keywords*: Used Insulation Oil (UIO), concrete, Sand, Heat of Hydration, Water absorption and Flexural strength.*

1. Introduction

Designing the concrete mix to be effective in all aspects has become essential in the current world. To make concrete better, different admixtures have been used since the Roman era. Admixtures are usually chemical solids or fluids or fine materials incorporated in concrete other than aggregates, cement and water. They improve various performance characteristics of concrete like workability, strength, durability, water reduction and even improve corrosion protection in reinforced cement concrete. It is incorporated in concrete as a certain percentage replacement or addition for weight of cement. Concrete casted without admixtures will not be suitable for our present climate and environmental conditions. They tend to fail and doesn't last till its designed life period. By introducing admixtures in concrete, it becomes easy to modify its fresh and hardened properties in accordance with our needs. With the help of admixtures, various special concrete for special applications are designed and applied in the construction sector.

Sustainable construction is now gaining awareness all over the world. Recycling and reusing materials and saving our existing natural resources by properly utilizing and managing them will contribute to sustainability. Research studies on using green admixtures i.e., reusable waste materials in concrete, testing and evaluating the properties, to recommend as admixture or not is the current focus. Generation of industrial and other wastes is still high and proper measures are to be implemented to prevent it from causing pollution to our surroundings.

Oil is a major waste once it is no more reusable. When disposed as such, it contaminates land and marine ecosystems causing pollution [2]. Water resources gets affected and becomes a serious problem to manage once it is leaked. Used engine oil of about 200 million gallons is disposed every year in the U.S by improper methods. This has caused contamination of groundwater supplies and drinking water has become harmful for consumption. Waste oil such as synthetic crude oil, mineral oil, engine oil and cooking oil should be discarded effectively without causing harm to surroundings. One way of properly making use of this waste oil is to use it as an admixture in concrete construction. Studies have justified that using new and waste oil as admixture caused changes in workability, improved strength at certain percentage addition and enhancing bonding effect between constituents by reducing pores in concrete matrix[1-5]. Moreover, waste oil is abundant and economical hence easily extracted and always available.

Insulation Oil is a mineral oil derived from petroleum. It has excellent electrical and heat insulation properties and is used in transformer to cool windings and prevent circuits from arcing. Insulation oil is different from lubrication oil. The former is used specifically to insulate parts of electrical components while the latter is used to reduce friction between machine parts. Used Insulation Oil (UIO) is the oil we used in our study as admixture. This ineffectual, black colored oil is derived after usage in transformer. Instead of discharging them directly into the environment, it would be a better solution if it can be used as an admixture thus reusing them effectively.

In this study, we compared the properties of workability, Compressive strength, Heat of Hydration and water absorption for conventional M25 grade concrete, 1%, 1.5% and 2% UIO added concrete. Cube specimens of size 15cmx15cmx15cm are casted for these four types and the above mentioned properties are comparatively studied. Change in workability is attributed due to oil acting as a lubricant between aggregates [1]. Improvement in compressive strength at a certain percentage [5] and since insulation oil is used, mild reduction in temperature as compared to conventional concrete are noted using infrared thermometer. Flexural strength increases because of good bonding between materials as oil is used. Durability property is compared using water absorption test and finally the best percentage of UIO added to concrete that satisfies all these properties are found.

2. Study of Materials

2.1 Cement

Cement used is OPC of 53 grade. As per IS 12269 – 1987 [8], the tests results are checked. The cement is free from lumps and moisture. The cement particles sank into water instead of floating on surface.

Table 1 Cement Properties.

S.No	Characteristics	Values	Unit
1.	Initial time of setting	30	minutes(min)
2.	Final time of setting	600	minutes(min)
3.	Soundness	3.2	millimeters(mm)
4.	Consistency	32.5	percentage (%)
5.	Specific gravity	3.15	no unit

2.2 Fine Aggregate

Construction sand of grading zone II is used. As per IS 383, the properties of sand are tested. The sand is to be free from organic matter and silt particles. [7]

Table 2 Sand Properties.

S.No	Characteristics	Values	Unit
1.	Specific gravity	2.52	no unit
2.	Maximum size	4.75	millimeters (mm)
3.	Moisture content	NIL	-
4.	Type	Construction M-sand	-
5.	Fineness modulus	3.1	no unit

2.3 Coarse Aggregate

Gravel that is locally available is used in the work. Testing is done as per IS 383 – 2019. Gravel is free from dust and the surface is dried well to remove moisture. The gravels chosen are angular. The flaky and elongated particles are removed. [7]

Table 3 Gravel Properties.

S.No	Characteristics	Values	Unit
1.	Specific gravity	2.65	no unit
2.	Type	Crushed angular	-
3.	Moisture content	NIL	-
4.	Water absorption	0.5	percentage (%)
5.	Abrasion value	10	percentage (%)

2.4 Similarities between Chemical Admixture and Used Insulation Oil

As mentioned earlier, Insulation Oil is primarily mineral oil – derivative of petroleum, consisting of Hydrocarbons as the key ingredient. The chemical composition consists of CaO, ZnO and SO3 adding at least 50%. It is also called Naphtenic Oil as this is actually a naphthalene based oil. The chemical admixtures like retarders consists of organic unrefined carbohydrates and Calcium and also inorganic oxides of zinc and lead. Super plasticizers include sulphonated naphthalene formaldehyde condensate which is again a naphthalene based hydrocarbon chemical. Also, the American Concrete Institute (ACI)

212.3 Rev10 gave a detailed report on chemical admixtures for concrete [9] which recommend use of mineral oil, petroleum extracts that block the pores in concrete acting as water proofers. Thus, UIO can be effectively used as alternative to chemical admixture in concrete.

3. Mix Design

The mix design for M25 concrete is done following IS 10262 2009. Dosage of 1%, 1.5% and 2% UIO by weight of cement added as admixture [10] [11]

Water to binder ratio is 0.48

3.1 Mix Proportions:

Normal conventional – M25 = 1: 1.48: 2.59

1.0% UIO = 1: 1.47: 2.57

1.5% UIO = 1: 1.47: 2.56

2.0% UIO = 1: 1.46: 2.55

4. Preparation of Cube Specimens

Batching is done for the raw materials as per mix proportions arrived. Followed by mixing with water, Fresh Concrete is prepared. Test on workability conducted to determine slump of different concrete. UIO is added in dosage of 1%, 1.5% and 2% for the same water to cement ratio during mixing. Casting is done in cube moulds of size 0.15×0.15×0.15 meters. Concrete is to be filled in 3 layers and tamped properly for proper compaction. The cubes are demoulded after 24 hours. These cubes are cured in water till the respective dates of testing of hardened concrete. In this study, tests are done at 3, 7, 14 and 28 days of curing.

Figure 1 Cast Cube Specimens

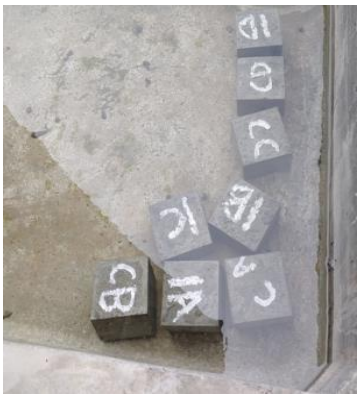

Figure 2 Curing Concrete Cubes

5. Experimental Observations

5.1 Workability

Table 4 Workability Test Results.

Type	Slump Value(mm)
Control mix (M25)	130
1% UIO	80
1.5% UIO	25
2% UIO	0(zero slump)

A graph is plotted for comparison of results,

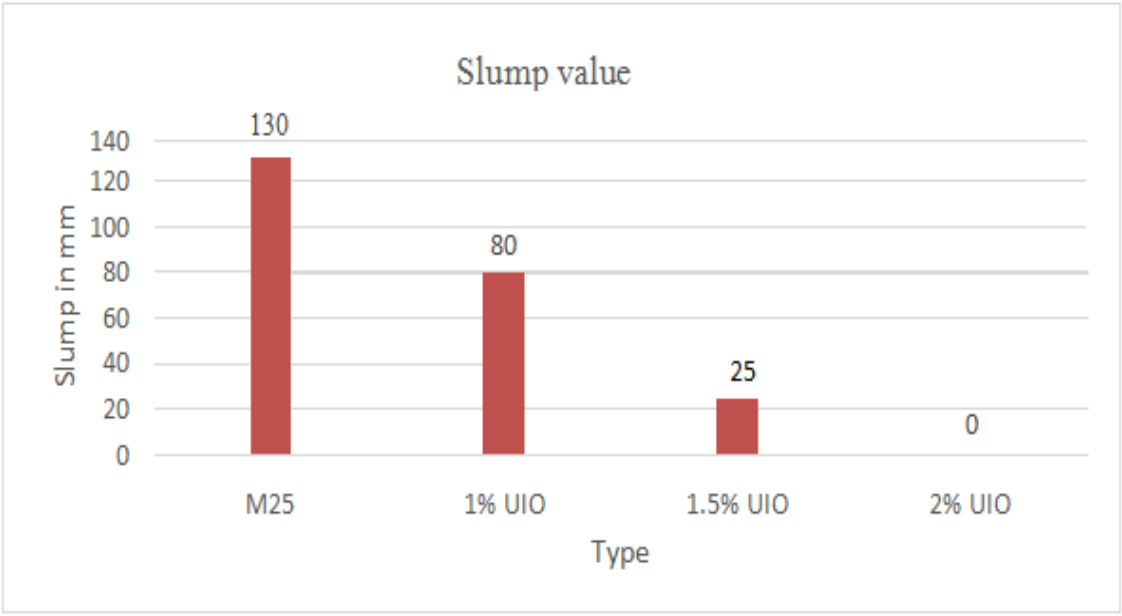

Figure 3 Workability by Slump Test

5.2 Heat of Hydration

Table 5 Heat of Hydration Test results.

Type	3rd day (°C)	7th day (°C)	14th day (°C)	28th day (°C)
Control mix(M25)	22.6	22.1	24.4	28.6
1% UIO	22.4	22.1	24.1	28.2
1.5% UIO	22.3	21.9	24	27.7
2% UIO	22.2	21.4	23.7	27.5

A line graph showing temperature variation is plotted,

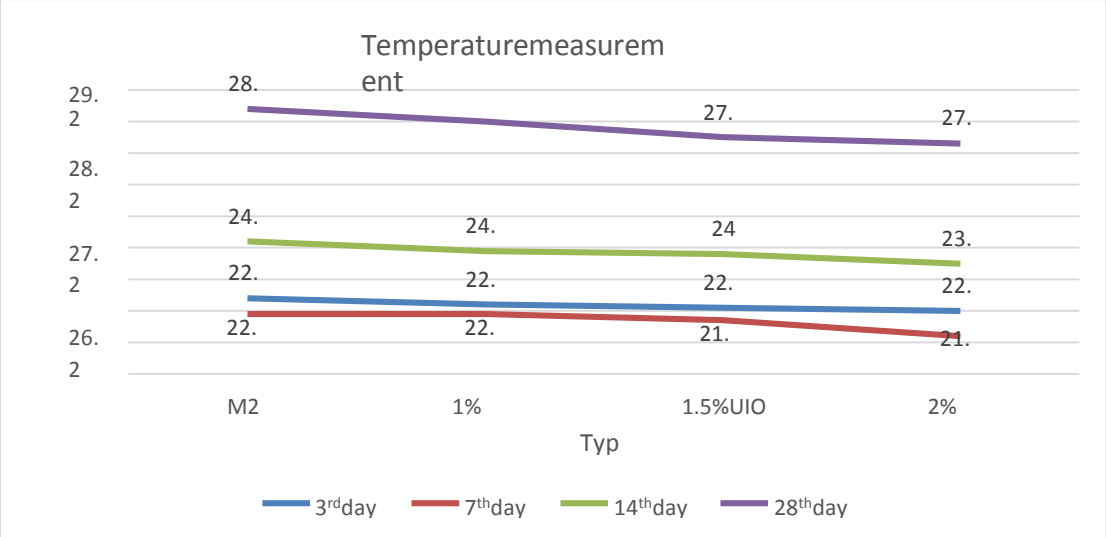

Figure 4 Heat of Hydration

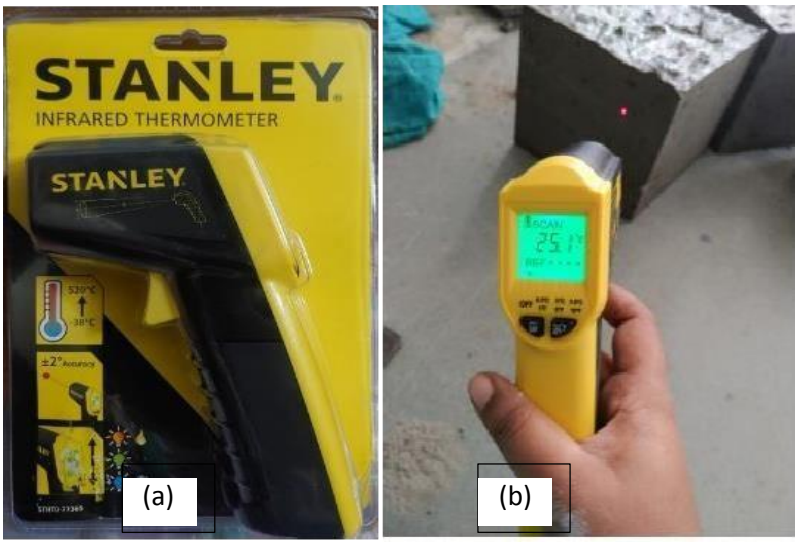

Figure 5 (a) Infrared Thermometer (b) Measuring surface Temperature

5.3 Water Absorption

Table 6 Water absorption – Conventional M25 concrete.

Sample	Dry density (kg/m^3) (B)	Wet density (kg/m^3) (A)	Water absorption= $\frac{A-B}{B}\times 100$ (%)
A	2267.25	2291.55	1.07
B	2285.92	2311.40	1.11
C	2249.77	2277.33	1.22
D	2242.37	2269.92	1.22

Table 7 Water absorption – 1% UIO Concrete.

Sample	Dry density (kg/m^3) (B)	Wet density (kg/m^3) (A)	Water absorption= $\frac{A-B}{B}\times 100$ (%)
A	2276.74	2297.48	0.91
B	2282.07	2305.77	1.03
C	2293.92	2317.92	1.04
D	2293.62	2319.40	1.12

Table 8 Water absorption – 1.5% UIO Concrete.

Sample	Dry density(kg/m^3) (B)	Wet density (kg/m^3) (A)	Water absorption= $\frac{A-B}{B}\times 100$ (%)
A	2261.628	2279.4	0.78
B	2288.59	2309.62	0.92
C	2279.11	2300.74	0.95
D	2291.85	2315.85	1.047

Table 9 Water absorption – 2% UIO Concrete.

Sample	Dry density (kg/m^3) (B)	Wet density (kg/m^3) (A)	Water absorption= $\frac{A-B}{B}\times 100$ (%)
A	2304.29	2318.8	0.63
B	2310.518	2326.81	0.7
C	2317.33	2338.674	0.89
D	2318.81	2338.96	0.86

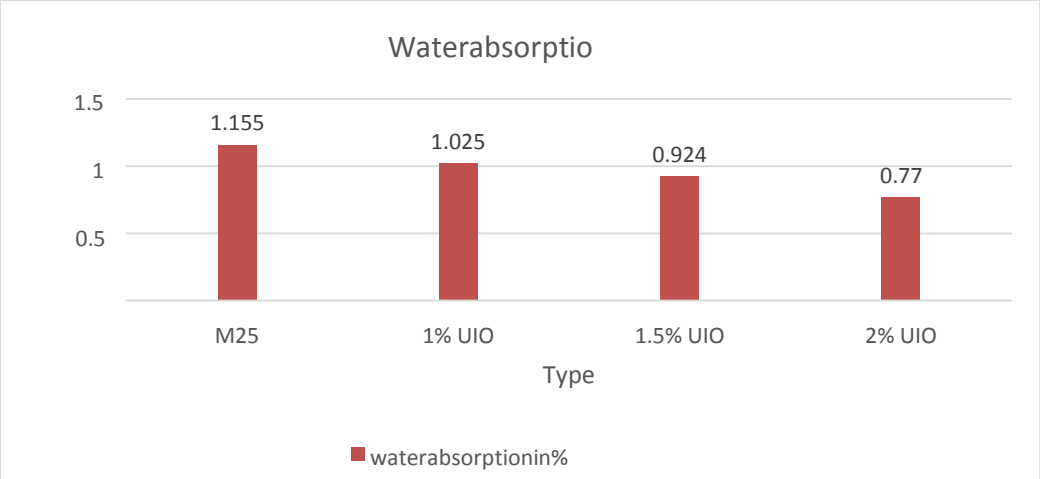

Figure 6 Water Absorption Test

5.4 Compressive Strength Test

Table 10 Compressive Strength Test Results.

Type	3rd day (N/mm2)	7th day (N/mm2)	14th day (N/mm2)	28th day (N/mm2)
Control mix(M25)	10.02	15.81	19.27	24.72
1% UIO	10.76	16.51	20.95	26.08
1.5% UIO	11.85	18.77	23.06	28.67
2% UIO	9.85	14.29	19.87	20.91

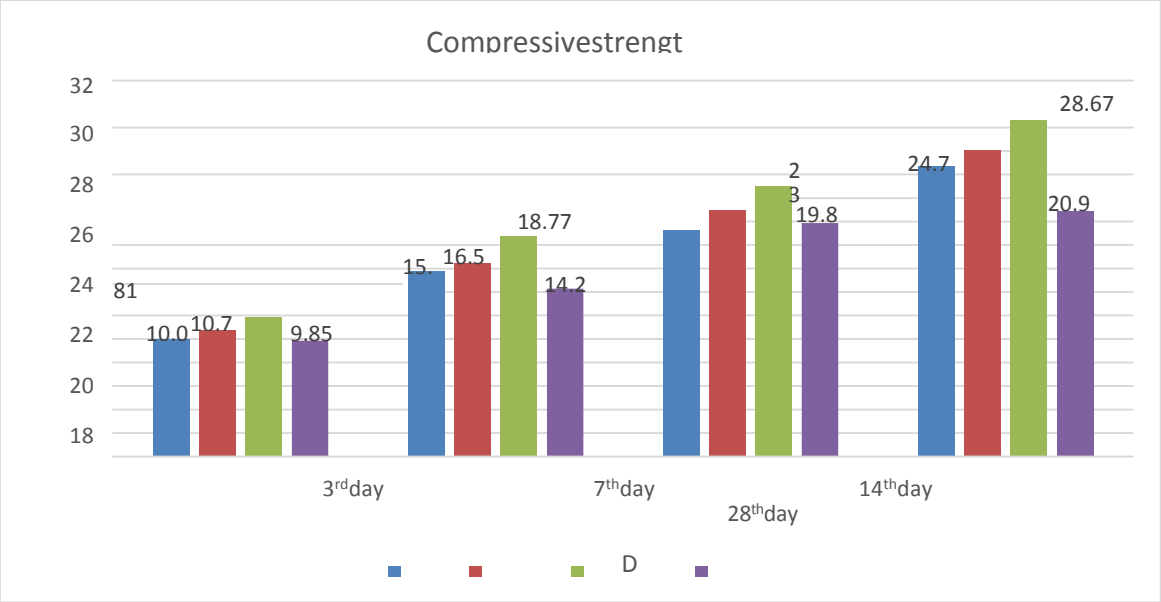

Figure 7 Compressive Strength

5.5 Flexural Strength

Flexural Test is done in beam specimens of size 10×10×50cm

Table 11 Flexural Strength Test Results.

Type	Flexural Strength(MPa)
Control mix (M25)	2.54
1% UIO	2.92
1.5% UIO	3.23
2% UIO	2.67

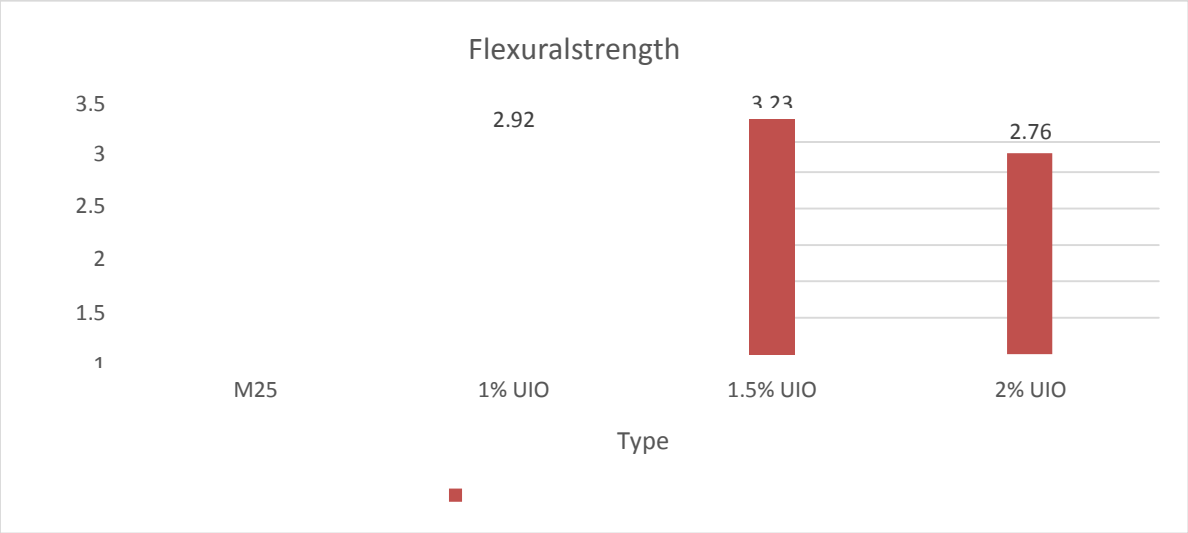

Figure 8 Flexural Strength Test

6. Results and Discussions

6.1 Workability

As per mix design, the conventional mix slump value is 125mm. The test result we obtained is 130mm which is up to the mark. The UIO added concrete mix was sticky and hard during mixing process. The UIO concrete became stiffer as dosage increases. At just 1% UIO concrete, the slump decreased to 80mm which is 38% decrease in workability. On 1.5% and 2% UIO, the concrete's slump value decreased drastically and reached 25mm and zero slump respectively. Emulsion of oil and water made the concrete stickier and stiffer while mixing. Even at slight increase in dosage, the fresh concrete tend to be thicker and denser. Hence, fresh concrete doesn't flow but rather remained firm while raising the mould. This confirms that UIO acts like a binder, not like cement but it binds all the raw materials and holds them intact that caused a decrease in workability. However, the waxy nature of the oil made the placing and compacting process uncomplicated.

6.2 Heat of Hydration

On checking the surface temperature of the specimens, we noticed small decrease in temperature as dosage increases. This skeptical results obtained for UIO added concrete [5] is compared with temperature of conventional concrete. At each increasing dosages, there is 0.2 degree Celsius decrease in temperature. There is a difference of nearly 0.7 degrees between conventional and 2% UIO added concrete. Just as insulation oil prevent heat transfer, UIO used in concrete tend to decrease the heat. As heat is reduced, this would prove to be a better solution for mass constructions where thermal cracking is a major issue.

6.3 Water Absorption

This test explains about durability of the concrete. When concrete is porous, durability will be less as water is absorbed. For conventional M25 concrete, water absorption should be at an average 3%. For all the specimens, the test results shows water absorption values at range of 0.7%-1.2% only. This would actually improve the compressive strength of cubes. Among the specimens, 2% UIO added concrete showed the lowest water absorption 0.77% and conventional M25 showed the overall maximum of 1.22%. The 1.5% UIO concrete showed 20% decrease in water absorption than M25 concrete. The oil being stiffer and viscous has contributed to decrease in water absorption by blocking the air voids and ITZ in concrete.

Compressive Strength

Compressive strength at 3, 7, 14 and 28 days are determined. For all cubes, there is steady rise in strength from 3rd day to the 28th day. Conventional M25 concrete showed near to 25MPa strength at 28 days. From the results below, it is seen that 1.5% UIO added concrete has achieved maximum strength in all days. Even at 1% UIO, there is 4% rise in strength than M25. However, there is sudden decrease in compressive strength at 2% UIO on all four days. This is because UIO prevent the formation of CSH gel by hydration. This also confirms why the temperature declines under increased dosage. The1.5% UIO added concrete has 12% more compressive strength than conventional concrete. The 2% UIO added concrete has 16% less compressive strength than conventional.

6.4 Flexural Strength Test

Flexural strength test is conducted at 7th day. For conventional M25, 1% and 1.5% UIO added concrete, the flexural strength rise to 2.54 MPa, 2.92 MPa and 3.23 MPa respectively. There is 27% increase in flexural strength at 1.5% UIO compared to control mix. But at 2% UIO, the flexural strengths lightly decreases but is still greater than M25. The rise in flexural strength at 1.5% UIO might be due to increase in bonding between aggregate and cement because of oil. Also, as the porosity is reduced at increasing dosages, there is increase in flexural strength for all UIO added specimens.

7. Conclusion

The conclusions made based on all the tests conducted and studied were listed below,

(1) Many studies reported that usage of waste oil actually increases workability, but this Used Insulation Oil which we adopted showed decrease in workability at increasing dosage at the same W/C ratio. This oil makes the concrete stiffer and dense at high dosages.

(2) The surface temperature measured using infrared thermometer showed 0.4 to 0.7 degree Celsius decrease in compressive strength at 2% UIO than control mix M25. This indicates that there is low heat of hydration taking place at increasing dosage. The skeptical results we arrived shows that just as insulation oil reduces heat in electrical appliances, this oil tend to stop the exothermic heat due to hydration. Thus UIO used in concrete would be suitable for mass construction applications where thermal cracking is a major problem.

(3) Water absorption by concrete reduced at increasing dosage of UIO. This means that the UIO added concrete has low porosity. The oil being highly viscous and stiffer has blocked the air spaces in the matrix.

(4) The compressive strength test results showed that at 1.5% dosage of UIO the strength attained is maximum at all the tested days. As dosage increased, the strength also increased but at 2% UIO the strength suddenly dropped and has 16% less compressive strength than M25. This drop is attributed to reduction in CSH formation as a result of hydration. The CSH gel contributes to strength development. As more oil is added, it retards the production of CSH by hydration. This also explains why there is decrease in temperature at 2% UIO.

(5) The flexural strength test result showed that 1.5% UIO concrete has better flexural strength than other types. This is because oil being thick and viscous forms a bond between aggregates and cement. Even at 2% UIO, the flexural strength is higher than control mix.

(6) From the results, 1.5% UIO is the best recommended dosage and is a suitable alternative to chemical admixture in concrete.

References

[1] Job, Olorunmeye&Achuenu, Emmanuel &Soji, Solomon & ITODO, Sunday (2017) Performance of Castor Oil as Admixture in Fresh Cementitious Matrix. International Journal of Civil Engineering. 4. 87-94. 10.14445/23488352/IJCE-V4I6P114.

[2] Alsadey, Salahaldein (2018) Effects of Used Engine Oil as Chemical Admixture in Concrete, International Journal of Energy and Sustainable development, Vol 3, No 2,

[3] pp 38-43

[4] Shahrabadi, Hamid &Vafaei, Davoud. (2015). Effect of kerosene impacted sand on compressive strength of concrete in different exposure conditions. 6. 2665-2672.

[5] Muwashee, Rawa.(2016) Effect of Used Cooking Oil on the characteristics of concrete including gap-graded aggregate. STM. 6.

[6] M Chandrasekar, S. KavithaKarthikeyan, G. Snekha, A. Vinothini (2016) Experimental investigation on usage of Waste Cooking Oil (WCO) in concrete making and adopting Innovative curing methods, International Journal of Engineering Research and Technology, Vol 5,Issue 4

[7] Chin, S.C. and Shafiq, N. and Nuruddin, F (2010) Structural Performance of Reinforced Concrete Beams Containing Used Engine Oil, International Conference on Sustainable Building and Infrastructure (ICSBI 2010), 15-17 June 2010, Kuala Lumpur Convention Centre.

[8] Indian Standards IS2386 Part 3,Method of Testing of Aggregates for Concrete(2021), Bureau of Indian Standards

[9] Indian Standards IS12269, Specification for OPC 53 grade (2013), Bureau of Indian Standards.

[10] American Concrete Institute 212.3R -16, Report on Chemical Admixtures for concrete(2016) [10]Indian Standards IS10262, Guidelines for concrete mix proportioning (2019), Bureau of IndianStandards

[11] M. S. Shetty, Concrete Technology, S Chand & Company Publishing, Edition 2022