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Experimental Investigation on Usage of Waste Cooking Oil (WCO) in Concrete Making and Adopting Innovative Curing Method

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***Abstract* - Throughout decades of development in the construction industry, there are a variety of chemical admixtures introduced to improve the concrete performance as desired. But the high cost and potential environmental dangers of using these chemical admixtures makes their usage restricted to mass constructions. In order to alleviate this current situation, this study was undertaken to assess the compatibility of using waste cooking oil (WCO) as a green admixture in concrete. Normally, curing process of concrete is done to manage the rate of heat of hydration. This study was also aimed at reducing the heat of hydration of concrete by introducing a whole new principle way of curing concrete, which is, curing the WCO added concrete in a water medium containing added extracts derived from vegetable and fruit peels (organic waste). This study was literally undertaken in a view to establish a whole new thought of proper utilization of these large amount of generated wastes (WCO and organic waste) in the construction sector and reducing the overall amount of these wastes which are queued up for disposal thereby, creating a low cost, sustainable and eco-friendly mode of concrete making.**

A short duration study (at 3, 7, 14 and 28 days of curing period) was conducted on the properties of conventional and different percentage (1, 1.5 and 2) of WCO added concrete. The conventional concrete cubes are cured with ordinary water and the WCO added concrete cubes are cured in water medium containing the extracts sourced from vegetable and fruit peels. The properties of concrete assessed are workability, heat of hydration and compressive strength. The results of these tests conducted on WCO added concrete specimens are compared with the results obtained from conventional concrete specimen. The thorough analyses of the test results were found to be satisfactory and the use of waste cooking oil as an admixture and adaptation of this innovative curing method proved to be successful in reducing the temperature of the concrete cubes.

Keywords – Waste Cooking Oil (WCO), Organic Waste, Innovative Curing, Heat Of Hydration In Concrete

1.INTRODUCTION

From the early ages, human population has been on constant rise in the world, and so there is an immense development in the food sector. In India, Food sector primarily includes the use of large quantities of cooking oil, which when used several times, becomes difficult to dispose it off in a proper environment-friendly way. Most of the waste cooking oil is illegally disposed by either mixing with natural water bodies (like rivers, lakes and ponds etc.) or by mixing with sewage water. From a survey conducted by IIT, it is estimated that, India produces around 9.2 million tons of waste cooking oil in a year which is highest in the world. So, there comes a need to find ways to dispose these large quantities of waste cooking oil in an efficient and economic manner. India is also one of the densely populated countries in the world and so, each day in addition to huge quantities of generated waste cooking oil, several thousand tons of solid wastes are also being generated. Almost 50% of the solid waste produced comes under organic putrescible category, which mainly consists of fruit and vegetable peels. Due to the negligence and poor maintenance by municipal authorities, each day several thousand tons of solid wastes are left scattered along roadsides, thereby creating litter. This strategy might provoke several dangerous health hazards to all living forms. In a densely populated country like India, the disease can be easily transmitted by vectors and can cause severe health ailments. And so, there arises a quick need to find ways to dispose these vegetable & fruit peel wastes in a proper manner, so as to prevent its decomposition in the open environment and spread of communicable diseases.

As we all see in construction industry, there are several attempts to improve the performance of concrete by addition of several miscellaneous new admixtures and also various curing methods. There are many researches still going on, in order to find a cost-cutting way to improve concrete performance. This experimental study is focused on utilizing the waste cooking oil as green admixture in concrete making and deriving the extracts from vegetable & fruit peel wastes and diluting the extract with water by adopting certain dilution ratios, and utilizing this water for curing purposes of concrete.

As we know that, there are several methods to cure the concrete, but all of the known methods use normal water as a prime source for curing, but we thought of an innovative idea of curing concrete which is, mixing certain quantity of vegetable and fruit peel extract with water and curing the concrete in it. By this way of curing, we expect to reduce the heat of hydration liberated from concrete. This study of adopting the curing method by vegetable and fruit peel extract is also aimed at altering the properties of concrete and expecting natural cooling effect on concrete. It has been estimated that, India generates around 960 million tons of solid waste annually. Of this, 350 million tons are organic wastes produced from agricultural sources. From a survey, it is estimated that about 18% of the vegetable and fruit production worth Rs.44000 crore is going as waste annually. These estimations prove our concept of curing using vegetable and fruit peel extract to be economically viable.

2. REVIEW OF LITERATURES

2.1 Strength and Durability properties of concrete with starch admixture by A.A.Akindahunsi & H.C.Uzoegbo: Studied the behavior and reactivity of starch admixture on the performance of concrete. The starch admixture used is

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comprised of cassava and maize. The starch is added in 0.5, 1.0, 1.5 and 2.0% by weight of cement. It was reported that starch acts like a retarding admixture and the compressive strength was increased up to 5.2% at the 28-day curing period in 0.5% addition of starch when compared to the control test specimen. It was also reported that the durability of concrete is increased by using starch.

2.2 Utilization of used engine oil in concrete as a chemical admixture by Dr. Gamal Elsayed Abdelaziz: Studied the potential use, the adaptability and the compatibility of using used-engine oil (UEO) as an admixture in concrete. It was reported that used engine oil showed the properties of both plasticizer and air entraining admixture. However, it was also reported that the 28 day compressive strength was slightly degraded due to the addition of used engine oil.

2.3 Properties of concrete containing used engine oil by Nasir Shafiq, Muhd Fadhil Nuruddin & Salmia Beddu: Investigated the reactivity of used engine oil as an air entraining admixture in concrete. It was reported that used engine oil increased the concrete slump by 18% to 38% and air content by 26% to 58% as compared to the slump of control concrete. However, it was also reported that there is no significant change in the compressive strength of concrete i.e., the compressive strength remained fairly the same for both control concrete and test concrete.

2.4 Utilization of pulp black liquor as an admixture in concrete by Paul Shaji, Anagha K J, Anju R Paithackal, Aswathy K P, Sukanya K S: Investigated the effect of using a waste (pulp black liquor- a waste from paper industry) as an admixture in concrete making. The pulp black liquor was added in 0.5, 1.0, 1.5, 2.0 2.5 % by weight of cement. It was reported that the workability is increased noticeably, the setting time is retarded and the compressive strength reached a maximum in 1.0% addition of pulp black liquor.

2.5 Effects of a locally sourced water reducing / retarding admixture on concrete by Ayorinde Oladiran, Olufikayo Aderinlewo & Moses Tanimola: Examined the effects and feasibility of adopting a locally available material as admixture in concrete. The orange tree leaves are powdered and used as green admixture in concrete. The admixture was added to the concrete mix in percentages of 1, 2, 5, 10 and 15 by weight of cement. It was reported that workability is increased and the 28 day compressive strength increased gradually for percentage addition of 1, 2 and 5. However, the compressive strength began to decrease gradually beyond 5 % addition of admixture i.e., in 10% and 15%.

2.6 Improvement of concrete properties made from recycled concrete aggregate using non-traditional admixture by Yehia A. Hassanean, M.M. Rashwan, Kamal A. Assaf, Khaledabd El Samee: Examined the reactivity and changes that took place in concrete when a waste from a vegetable oil industry called as “soap stock” is used as green admixture in concrete. It was reported that the compressive strength, splitting tensile strength, bond and flexural strength has increased on addition of 0.9% soap stock by weight of cement to concrete.

2.7 Cypress tree extract as an eco-friendly admixture in concrete by Abraham M. Woldemariam, Walter O. Oyawa, Silvester O. Abuodha: Studied the feasibility, adaptability and reactivity of using green admixture-cypress tree extract in concrete. The cypress tree extract was added in 5, 10, 15 and 20% by weight of cement and its behavior is studied. It was reported that cypress tree extract increased the initial setting time and workability of concrete. It was also found from the study that the compressive strength increases with the percentage increase in addition of cypress tree extract.

2.8 Used cooking oil as a green chemical admixture in concrete by B. Salmia, Zakaria Che Muda, Md. Ashraful Alam, L.M. Sidek & B. Hidayah: Investigated the compatibility of using used cooking oil as a green admixture in concrete. The used cooking oil was added in 0.25, 0.50, 0.75, 1.00, 1.50 and 2.00% to the weight of cement. It was reported that the used cooking oil adhered well with the concrete-matrix and the compressive strength was increased when compared to the control specimen. It was recommended that the optimum dosage addition of used cooking oil was 1.50%

2.9 Inferences from the Literatures: Upon studying all the previous papers, a clear picture was made about the different kinds of admixtures used in concrete and their reactivity with the concrete matrix. It was observed that for a material to be used as admixture, it must satisfy the general characteristics of compatibility with concrete-matrix and the degree of availability of that material. It was also noted that the chemical constituent of a material can alter the properties and performance of the concrete. Also, the adopted dosage of admixture also plays a major role in the characteristics of concrete. From the cited literatures, it was expected that experimenting with waste cooking oil on concrete may pave a way for the introduction of low cost admixtures in the construction field and also may bring a sustainable ecofriendly method of concrete making by utilizing the wastes in a beneficial manner. On this thought, this experimental investigation was undertaken and commenced.

3 STUDY OF MATERIALS

The materials used in this study are cement, fine aggregate, coarse aggregate, waste cooking oil and vegetable and fruit peel extract.

3.1 Cement

IS mark 43 grade Ordinary Portland Cement was used for all concrete mixes. The cement used was fresh, chill and without any lumps.

Table 1: Properties of cement

S. no	Parameters	Values	Standard value
1	Normal consistency	33%	IS 4031(part 4) - 1988
2	Specific gravity	3.15	IS 2720(part3/sec 1) - 1980
3	Initial setting time (min)	30	>30 IS 4031 (part 5) - 1988
4	Final setting time (min)	600	= 600 IS 4031(part 5) - 1988
5	Fineness (%)	0.61	IS 4031 (part 2)

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3.2 Coarse aggregate

Locally available coarse aggregate having the maximum size of 20mm were used in this work. Testing of coarse aggregate was done as per IS 383-1970. The aggregates were first sieved in 19mm sieve and then sieved again in 13.5 mm sieve. The aggregates passing through 19mm sieve and retained in 13.5mm sieve are used in this work. They were then washed to remove dust and dirt and are surface dried to expel the surface moisture.

Table 2: Properties of Coarse Aggregate

S no	Properties	Values
1	Type	Crushed
2	Maximum Size	20mm
3	Specific Gravity	3.08
4	Water Absorption	0.5%
5	Moisture Content	NIL
6	Impact strength (%)	30.9

3.3 Fine Aggregate

The sand used for the experimental program was locally procured and confirmed to grading zone 2 as per IS 383 – 1970. The sand was first sieved through 4.5mm sieve to remove any particles greater than 4.75mm and then washed to remove dust, clay and foreign particles.

Table 3: Properties of fine aggregate

S.no	Properties	Values
1	Type	Uncrushed (natural)
2	Maximum size	4.75mm
3	Specific gravity	2.81
4	Moisture content	NIL
5	Fineness modulus	3.079

3.4 Vegetable and fruit peel extract

The vegetable and fruit peels are acquired from dump yards and local vendors. These vegetable and fruit peels are then washed with water to remove the dirt and then air-dried to expel the moisture out in prior to grinding. The vegetable and fruit peels are chopped into smaller pieces and grinded in a mixer. The extract is then obtained by filtering out the grinded paste by means of a dry cloth and it is stored in a container and kept away from direct sunlight.

Table 4: pH, Turbidity and Dissolved oxygen values

S.no	Parameters	Ordinary water	Sample extract
1	pH value	7.34	4.66
2	Turbidity value (NTU)	0	54.4
3	Dissolved oxygen (mg/l)	22	0

Table 5: Determination of solids in ordinary water

Solids	Total Solids (mg/l)	Dissolved Solids (mg/l)	Suspended Solids (mg/l)
Total	3	2	1
Fixed	1	0	1
Volatile	2	2	0

Table 6: Determination of solids in sample extract

Solids	Total Solids (mg/l)	Dissolved Solids (mg/l)	Suspended Solids (mg/l)
Total	76	88	12
Fixed	26	26	0
Volatile	50	62	12

4 MIX DESIGN

The mix design was prepared in accordance with IS 10262-1982.

Characteristic compressive strength required in 28 days = 20 N/mm^2

Arrived mix proportions:
Conventional (without admixture) = 1: 1.62: 2.91
For 1.0% addition of waste cooking oil = 1: 1.61: 2.89
For 1.5% addition of waste cooking oil = 1: 1.61: 2.88
For 2.0% addition of waste cooking oil = 1: 1.60: 2.87

5 CASTING OF CONCRETE CUBES

In this experimental program, waste cooking oil is added as an admixture in percentages of 1, 1.5 and 2 to the weight of cement. For each percentage addition of waste cooking oil, 12 cubes were casted in an aim to test 3 cubes for its compressive strength on 3 days, 7 days, 14 days and 28 days of curing period and taking the average compressive strength of 3 cubes as the final compressive strength of each testing period. The compressive strength of oil added concrete cubes are compared with the compressive strength of conventionally casted concrete cubes and for this comparison, 12 conventional cubes are casted for testing every 3 cubes at 3,7,14 and 28 days of curing period. Initially, the cement and the aggregates are weight batched and dry mixed thoroughly in a rotating tilting drum mixer. Then, required quantity of water is added and mixed thoroughly to get a concrete mix of uniform consistency. Then, waste cooking oil is added at the time of mixing in various mentioned percentages. The percentage of waste cooking oil is increased by 0.5 percent in each addition. The concrete is filled into the cube moulds (150mmx150mmx150mm) in 3 layers and each layer is compacted by means of inducing mechanical vibration, which should not exceed 15 seconds. The stripping time adopted is 24 hours from the time of casting of cubes in the molds and then the concrete cubes are subjected to curing. The conventional concrete cubes are cured by normal curing method (moist curing) while the waste cooking oil (WCO) added concrete cubes are cured by the "innovative curing method" (water medium containing vegetable and fruit peel extracts).

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6 OBSERVATIONS MADE FROM INNOVATIVE CURING METHOD

As the extracts are derived in a concentrated form, (refer amount of solids present in extract as given in table 6) it is necessary to dilute the extracts with ordinary water in order to obtain a proper curing medium. The dilution ratio adopted is, 1 liter of ordinary water with 25 ml of the concentrates from vegetable and fruit peels. The curing of various percentages of oil added concrete cubes is done in a PVC barrel.

Figure 1: PVC barrel

Figure 2: WCO added cubes in Curing medium

As the curing medium containing the extracts is organic in nature, the organic matters tend to decompose over time due to the advent of microbes, atmospheric gases and sunlight. A series of biological reactions were observed during the entire 28 days of curing regime. The nature of the biological reactions, physical processes and the chemical processes taking place summarized as follows:

6.1 Physical processes

Dilution and dispersion: When the extract containing the putrescible organic matter is diluted in ordinary water, it gets slowly dispersed. This action results in diminishing the concentration of organic matter in extract and increases the PH value of solution due to dilution.
Sedimentation: The settleable solids present in raw extract settles down to the bottom of the barrel. The detention time period for complete sedimentation of the solids was found to be 4-6 hours.
Effect of sunlight: Normally the sunlight has a bleaching and stabilizing effect on bacteria. The sunlight helps certain micro-organisms present in curing medium to derive energy and converts the microbes into organic sludge. This organic sludge will also tend to settle down.

6.2 Chemical processes

Oxidation: The ordinary water contains dissolved oxygen in it. So, when the organic matter present in the extract reacts with the dissolved oxygen present in ordinary water, the oxidation of organic matter takes place. Here the atmospheric oxygen has no major effect because the water in the curing medium is stagnant and undisturbed. The oxidation conditions are found to prevail for the first initial 4 days of curing.

Reduction: Reduction occurs due to hydrolysis of organic matter settled at the bottom either chemically or biologically. Anaerobic bacteria splits the complex organic constituents present in the curing medium into liquids and gases. The various factors on which the reduction process depends are,

- Temperature
- Available dissolved oxygen
- Type of organic matter present

The temperature is the main factor which affects the rate of biological and chemical activities. Due to the anaerobic decomposition, the putrescible organic matter tends to decompose and creates a foul odour due to the release of gases like methane, carbon dioxide and hydrogen sulphide. These gases create bubbles at the surface and the masses of sludge (end product of anaerobic decomposition) forms an ugly scum layer at the surface. Due to the anaerobic decomposition, it was observed that typical bottom worms such as limnodrilus hoffmeisteri, tubifex and sphaerotilusnatans occurs. The dissolved oxygen of the curing medium drops to zero and the water in curing barrel appears greyish and darker.

In order to clearly assess the importance of temperature in the degree of decomposition, we have decided to measure the surface temperature of the curing medium each day with the use of an infra-red thermometer. This thermometer spots a laser infra-red beam directly onto the target and the temperature is recorded digitally on the screen, without making any physical contact with the target.

Figure 3: Infrared Thermometer for measuring Surface Temperature

Figure 4: Measurement of Surface Temperature of Curing Medium (water) in normal curing tank and PVC barrel

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Table 7: Comparison of Surface Temperature of Water during the entire 28 Days of Curing

Days	Recorded Temperature of water (in degree Celsius)				Inferences
	Normal curing		Innovative curing (in barrel)		
	9.30 AM	1.30 PM	9.30 AM	1.30 PM	
1	28.2	28.3	28.4	28.4	Sedimentation of suspended solids
2	28.1	28.3	28.3	28.5	Initiation and completion of aerobic decomposition
3	28.2	28.5	28.3	28.6	
4	28.6	28.8	28.8	29.0	
5	28.5	28.7	28.8	29.2	Influence of sunlight and initiation of anaerobic decomposition
6	28.8	29.0	29.1	29.5	
7	29.2	29.6	29.8	30.8	
8	28.2	28.6	31.4	31.5	
9	28.8	29.4	31.6	31.8	Breakdown of complex organic matter into sludge by the effect of anaerobic bacteria
10	28.2	28.7	32.1	32.1	
11	29.0	29.4	32.6	32.8	
12	27.2	27.6	32.8	33.2	
13	30.2	30.6	33.4	33.4	As a result of anaerobic decomposition, there is an evolution of foul odour due to the release of gases like methane, carbon di oxide and hydrogen sulphide and development of several types of bottom worms and sludge worms.
14	29.8	30.4	33.4	33.5	
15	29.9	30.3	33.6	33.8	
16	30.5	30.9	33.8	34.0	
17	28.9	30.2	33.6	33.9	
18	28.6	28.8	33.8	34.1	
19	30.6	32.0	34.1	34.2	
20	29.3	29.8	34.0	34.4	
21	29.8	30.6	33.6	33.6	Anaerobic conditions still prevail and there is a development of ugly scum layer on the top surface of curing medium. However, the degree of anaerobic decomposition decreases with the increase in age of curing medium.
22	31.8	32.3	33.8	34.1	
23	29.7	30.1	32.9	33.0	
24	30.6	30.8	33.1	33.6	
25	31.6	31.8	32.8	32.8	
26	29.8	30.4	32.6	32.7	
27	28.7	31.6	31.7	31.4	
28	29.7	30.4	31.0	30.6	

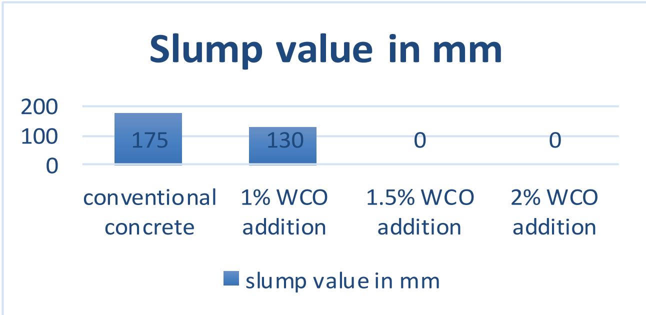
Before conducting the compressive strength test on the end of different curing days (3, 7, 14 and 28), the cubes were taken out and wiped off clean with a dry cloth and the surface temperature of conventional concrete cubes (cured in ordinary water) and the different percentage of oil added concrete cubes (cured in a water medium containing organic matter sourced from vegetable and fruit peels) are also measured in order to determine whether there is a corresponding change in the heat of hydration of concrete achieved from the innovative curing method, in comparison with normal curing method.

7 RESULTS AND DISCUSSIONS

7.1 Workability

The slump cone test results showed that the workability is good in the case of conventional concrete mix (which had a slump value of 175mm). However, the slump value is reduced to 130mm for the concrete mix containing 1% of waste cooking oil. For 1.5% and 2% of WCO addition, the concrete mix resulted in true slump without any subsidence. This implies that the waste cooking oil acts like a binder in the concrete and the increase in addition of WCO results in decrease in slump value. But however due to the viscosity (fluidity) and waxy nature of the WCO, the workability of the concrete mix even in 1.5% and 2% addition of WCO, remained satisfactory.

Chart 1: Comparison of Slump Values



7.2 Heat of Hydration

By comparing the surface temperature of conventional concrete cubes (cured in ordinary water) and different percentage of WCO added concrete cubes (cured in a water medium containing vegetable and fruit peel extracts) at the end of 3, 7, 14 and 28 days of curing period, it was found that the surface temperature of WCO added concrete cubes (which were cured in PVC barrel) remained 3 to 4 degree Celsius lesser than the surface temperature of conventional concrete cubes (which were cured in ordinary water).

Figure 5: Measurement of Surface Temperature of Concrete Cubes Using Infrared Thermometer

Table 8: Comparison of Surface Temperature of Conventional versus various percentage of WCO added Concrete cubes

Age Of Curing (In Days)	Recorded Average Surface Temperature Of Concrete Cubes (In Degree Celsius)	
	Conventional Concrete Cubes Cured in Ordinary Water	Different Percentage Of WCO Added Concrete Cubes Cured by Innovative Curing Method
3	29.6	27.8
7	32.4	30.2
14	32.6	29.6
28	33.2	30.1

The reason for the comparatively lower temperature of the WCO added concrete cubes is due to the series of biological reactions which took place in the curing medium containing the vegetable and fruit peel extracts. This is explained in detail below, when water is added to cement, the exothermic reaction starts and the heat evolved during this process is termed as the 'heat of hydration'. In this case, this heat of hydration is suppressed or lowered due to the anaerobic decomposition phase which taken place in the curing medium and also due to the heat absorption capacity (lubricating

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property) of WCO present in the concrete matrix. The advent of anaerobic decomposition phase increases the normal temperature of water and when this rise in temperature wastages in the surroundings. This also paves a way for sustainable eco-friendly construction of concrete structures and also reduces the amount of these generated wastages which are queued up for disposal.

7.3 Compressive Strength

The compressive strength test was conducted on both conventional and different percentage of WCO added concrete cubes at the end of 3, 7, 14 and 28 days of curing period. From the below table, it is clear that 1.5% WCO addition gave satisfactory results on compressive strength. The reason for ultimate variations in compressive strength of other percentages of WCO added concrete cubes is due to the biological decomposition reactions which alters the pH of the curing medium and also the chemical constituents of water. However, the maximum compressive strength (21.53 N/mm^2) was achieved in 1.5% WCO addition.

Table 9: Compressive Strength Test Results for M20 Grade concrete

Percentage of WCO added	Compressive strength (N/mm^2)			
	3rd day	7th day	14th day	28th day
0	5.02	9.50	13.48	20.97
1	5.65	9.04	11.08	16.63
1.5	6.55	9.06	14.95	21.53
2	6.27	8.88	11.34	17.96

8 CONCLUSION

The following conclusions were made based on the test results:

a) The increase in percentage addition of waste cooking oil decreased the workability of concrete at a constant water-cement ratio (i.e. 0.5). Hence, the waste cooking oil can be used as a low cost perfect binder in concrete.
b) The positive result obtained from the new curing technique has shown a considerable reduction in the heat of hydration, which paves a whole new, low cost and sustainable way of controlling, managing and reducing the rate of heat of hydration of concrete especially in hot weather concreting.
c) The satisfactory result obtained from the compressive strength WCO added concrete cubes also proves the suitability and compatibility of using waste cooking oil as admixture in concrete matrix.
d) The percentage increase in average compressive strength of 1.5% WCO added concrete cubes in comparison with conventional concrete cubes on 3rd day was 30.47%. However, the compressive strength of 1.5% WCO added concrete cubes on 7th day decreased to 4.63%, when compared with compressive strength of conventional concrete cubes. The compressive strength of 1.5% WCO added concrete cubes again showed an incremental percentage value of 10.9% and 2.67% on 14th and 28th day respectively in comparison with the compressive strength of conventional concrete cubes at the same days of testing. Hence from these results, the optimum dosage of waste cooking oil (WCO) was found out to be 1.5%.
e) The reduction in the heat of hydration as achieved from the new way of curing might change the existing perceptions regarding the thermal conductivity (heat transmitting) characteristics of concrete structures. From this research, it is concluded that, if this new way of curing method is practiced, one can achieve thermal comfort (reduction in heat - comparatively cooler than concrete structures which were cured by ordinary water) naturally in the interior of concrete structures.
f) From the test results, it was found that waste cooking oil adhered well with the concrete matrix and therefore, it is suitable for use as an admixture and it also proves to be a good alternative to high cost chemical admixtures.

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