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PROPERTIES OF CONCRETE CONTAINING CRUSHED LIMESTONE AS TOTAL REPLACEMENT OF NATURAL SAND AND RECYCLED ENGINE OIL

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PROPERTIES OF CONCRETE CONTAINING CRUSHED LIMESTONE AS TOTAL REPLACEMENT OF NATURAL SAND AND RECYCLED ENGINE OIL

Abstract

The rapid growth in the construction industry at the global level has made concrete the most widely used construction material throughout the world. Accordingly, the consumption of natural sand which is one the main raw material constituent of concrete is continuously growing. The demand for river sand is highly increasing due to its scarcity in the market. Manufactured sand produced by crushed rock is being considered as an appropriate alternative to replace river sand in concrete. In recent years, there is a growing interest in the use of crushed sand obtained from limestone quarries in some countries where river sand is not widely available". The objective of this study is to investigate the effect of total replacement of the natural sand by fine aggregates obtained from crushed limestone. However, it needs more research on the crushed stone fine aggregates to reveal its engineering properties prior to utilization in concrete. Another objective of this study is to study the effect of using the waste engine oil as partial replacement of water reducing admixture. The use of waste engine oil in concrete is beneficial for the environment. It is to be noted that some countries are recycling this used oil but others are throwing it in the sea and harming the marine life. In this paper, different combinations and grading of fine lime stone and coarse aggregates were tried in order to attain the optimal proportion that provide an acceptable concrete performance in terms of workability and compressive strength. Also, different percentages of admixture replacement ranging from zero to one hundred percent of the used engine oil were tried in the selected optimal mixture proportion. The final selected proportion using engine oil and crushed limestone could be considered as an economical solution and friendly environmental concrete product.

Keywords

Concrete Limestone Fines Engine Oil

1. INTRODUCTION

The rapid increase in population and human activities globally have led to an enormous generation of wastes (Khatib et al.2019). There is a current trend all over the world to look for the utilization of processed and unprocessed industrial by-products and domestic wastes as raw materials in cement and concrete (Hamad et al. 2003). Waste generation is one of the main problem facing the modern world (Baalbaki et al. 2019). There are different waste products coming from different industries like the coal power, steel and municipal solid waste industries. It is possible that plenty of these wastes can be used in the production of concrete (Charbaji et al. 2018). “Nowadays limestone has been widely used to add or replace a part of ordinary Portland cement (CEM I) to produce Portland limestone cement and Portland composite cement” (El Kordi et al.2014). It may be used to replace fine natural sand in concrete also. This has a positive environmental effect due to the increasing cost of waste disposal and due to the strict environmental laws.

Patil et al. (2018) applied many tests to check the replacement of the natural sand by crushed sand from jaw crushers. When replacement of natural sand by crushed sand ranged from 10% to 30% the compressive strength increased. Balapgol et al. (2002) reported that concrete with stone dust replacing 50% of natural sand as a fine aggregate yielded 10% higher compressive strength and 24% higher tensile strength. Zimar et al. (2017) found that the workability slightly decreases after the replacement of natural sand by crushed sand. Tsivillis et al. (2003) have reported that substitution of 15% of fines by weight of cement slightly decreases the concrete sorptivity. Menadi et al. (2009) mentioned that the resistance to chloride-ion penetration and gas permeability decreased for all concrete mixtures with the inclusion of 15% limestone fines as sand replacement.

For used engine oil, as known engines need oil to perform and work in an efficient way, and after a period of time this oil should be removed and replaced by new oil. This used oil may be used in many domains which would save money and help us keeping the environment clean and clear, since it is estimated that around 55% of worldwide used engine oil are being released into the environment, while the remaining 45% are collected by the municipalities and institutions which work on recycling and usage of this oil (El Fadel et al. 2011). This oil contains barium, dirt, sulfur, burnt carbon and ash. These contaminants can harm the water; 1 gallon of used engine oil can contaminate 100 million gallons of fresh water.

Shafiq et al. (2011) found that the slump of concrete increased when used engine oil was added to the mix (0.15% of cement mass). Assad (2013) concluded that used engine oil can be disposed in concrete provided a certain concentration threshold of around 0.3% of cement mass is not exceeded. The addition of used engine oil below such threshold improves to a limited extent concrete workability. For the compressive strength of concrete, at the age of 28 days, it decreased by 5% (Shafiq et al. 2011).

2. EXPERIMENTAL WORK

2.1 Materials and Concrete Mixtures

Two sets of mixes were prepared in this investigation. The purpose of the first set was to test the full replacement of natural sand by crushed limestone (LS). The second set of mixes investigated the addition of synthetic UEO (used engine oil) to partially replace the chemical admixtures. The maximum coarse aggregate (CA 20), smaller coarse aggregate (CA 10), and fine aggregate size (LF 5) were 20mm, 10mm, and 5mm respectively. The crushed limestone fines (LF 3) maximum size was 3mm and it was produced by modifying the inner parts of the jaw crusher to make the crushing process harder, and by using different size of sieves in the screening process. The cement used was Portland cement from Holcim company. The admixture used is a super plasticizer CF 101 (code of the item) from Sodamco. The water to cement (W/C) ratio for all mixes was 0.48. Figures 5 and 6 shows the materials used.

For the first set of the mixes, sand was replaced completely by limestone fines, the control mix was the mix used by a batching plant in Beqaa area which contains natural sand. The variable in these mixes was the grading distribution of aggregates as indicated in table 1. Details of the mixtures proportion are given in table 6. M60A40F indicates that mix ingredients are 60% coarse aggregates and 40% fine aggregates. The control mix used is based on 350 kg/m3 cement content. The overall distribution is given in the table as percentage of total aggregate.

As shown in table 7, M25 indicates that only 25% of the admixtures are replaced by used engine oil UEO, so the number in the mix code in table 7 indicates the % of replacement. It is to be noted that adjustments were done to the portions after testing the absorption and moisture content of the aggregates used.

Table 1: % of aggregates in concrete mixes

Mix Ref.*	Coarse 20	Coarse 10	LF 5	LF 3
M60A40F	30	30	20	20
M55A45F	25	30	25	20
M50A50F	25	25	25	25

Table 2: Sieve results for CA (20mm Max size)

Sample Weight: 2508.7g

sieve size, mm	**37.5**	**25**	**19**	**12.5**	**9.5**	**4.75**	**2.36**	**1.18**	**Pan**
Retained weight	0	0	29.2	1186.3	1143.6	121.2	0	0	28.4
% Retained	0.0	0.0	1.2	47.3	45.6	4.8	0.0	0.0	1.1
Cum. Retained %	0.0	0.0	1.2	48.5	94.0	98.9	98.9	98.9	100.0
Passing %	**100.0**	**100.0**	**98.8**	**51.5**	**6.0**	**1.1**	**1.1**	**1.1**	**0.0**

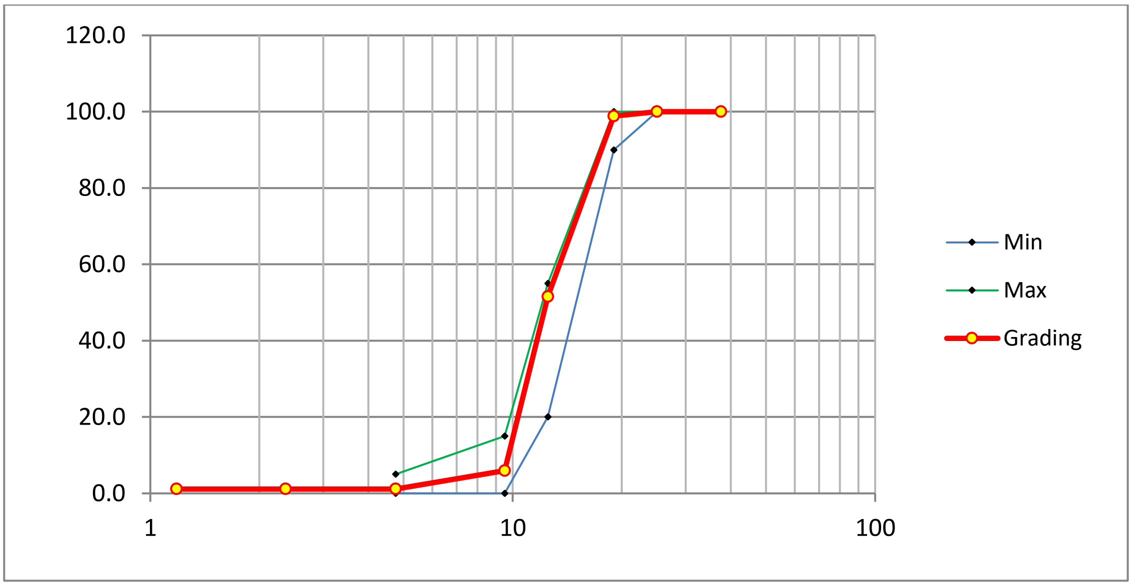

Fig.1: Sieve Analysis for Coarse Aggregates (20mm Max size)

Table 3: Sieve results for CA (10mm Max size)

Sample Weight: 1981.1g

sieve size, mm	**37.5**	**25**	**19**	**12.5**	**9.5**	**4.75**	**2.36**	**1.18**	**Pan**
Retained weight	0.0	0.0	0.0	0.0	33.5	1645.2	200.2	21.5	80.7
% Retained	0.0	0.0	0.0	0.0	1.7	83.0	10.1	1.1	4.1
Cum. Retained %	0.0	0.0	0.0	0.0	1.7	84.7	94.8	95.9	100.0
Passing %	**100.0**	**100.0**	**100.0**	**100.0**	**98.3**	**15.3**	**5.2**	**4.1**	**0.0**

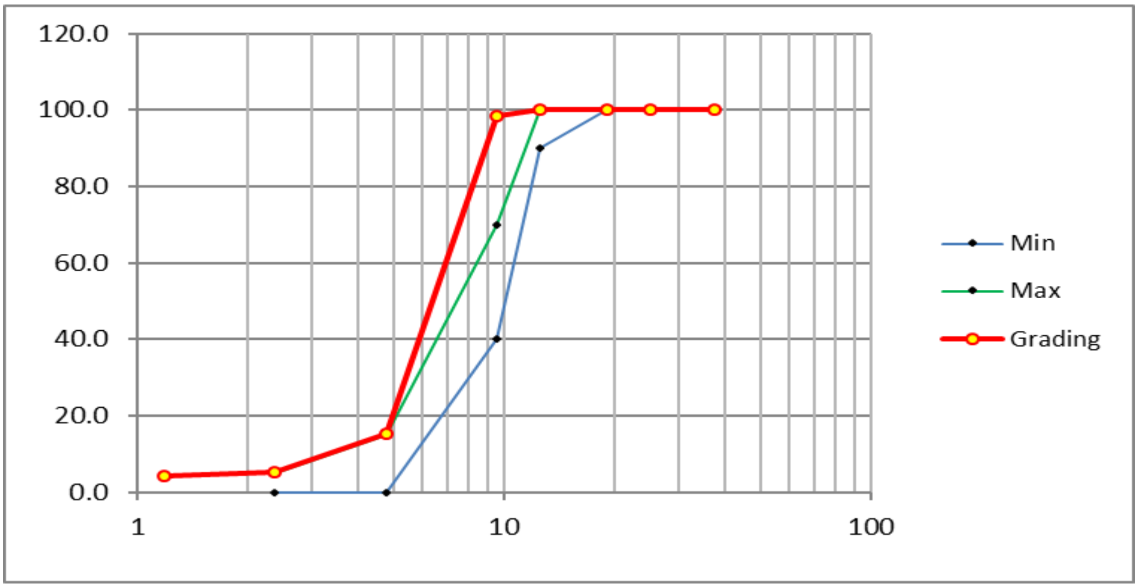

Fig.2: Sieve Analysis for Coarse Aggregates (10mm Max size)

Table 4: Sieve results for LF 5

Sample Weight: 1038.1g

sieve size, mm	**9.5**	**4.75**	**2.36**	**1.18**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**
Retained weight	0.0	46.6	350.3	151.4	191.0	84.1	60.5	24.0	130.2
% Retained	0.0	4.5	33.7	14.6	18.4	8.1	5.8	2.3	12.5
Cum. Retained %	0.0	4.5	38.2	52.8	71.2	79.3	85.1	87.5	100.0
Passing %	**100.0**	**95.5**	**61.8**	**47.2**	**28.8**	**20.7**	**14.9**	**12.5**	**0.0**

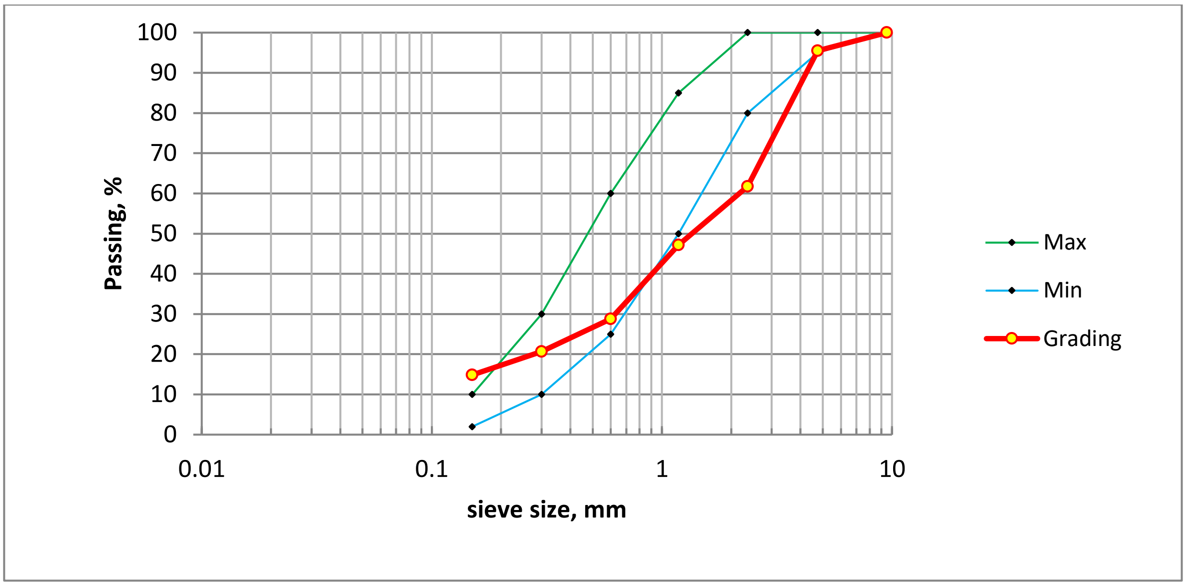

Fig.3: Sieve Analysis for LF 5

Table 5: Sieve results for LF 3

Sample Weight: 1081.1g

sieve size, mm	**9.5**	**4.75**	**2.36**	**1.18**	**0.600**	**0.300**	**0.150**	**0.075**	**Pan**
Retained weight	0.0	5.0	9.0	13.3	137.0	506.9	305.0	19.7	85.2
% Retained	0.0	0.5	0.8	1.2	12.7	46.9	28.2	1.8	7.9
Cum. Retained %	0.0	0.5	1.3	2.5	15.2	62.1	90.3	92.1	100.0
Passing %	**100.0**	**99.5**	**98.7**	**97.5**	**84.8**	**37.9**	**9.7**	**7.9**	**0.0**

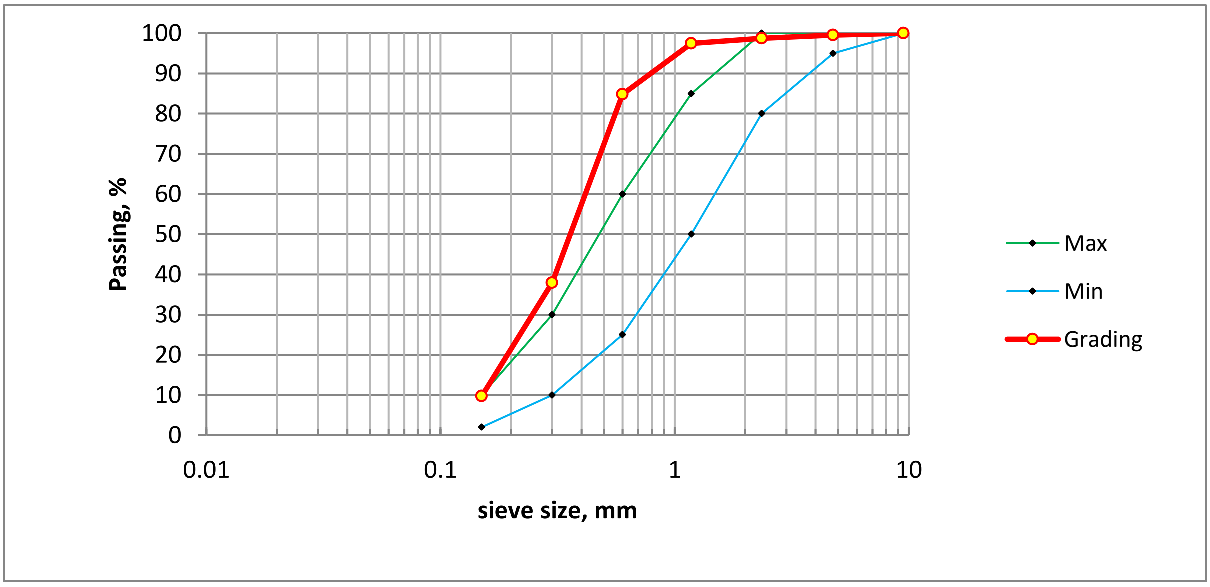

Fig.4: Sieve Analysis for LF 3

Table 6: Details of concrete mixtures proportions in kg/m3

Mix Ref.	Cement	Water	CA 20	CA 10	LF 5	LF 3	Sand	Admixture
Control 1	350	168	438	525	437	0	350	7.6
M60A40F	350	125	525	537	365	370	0	7.6
M55A45F	350	120	438	537	457	370	0	7.6
M50A50F	350	120	438	447	457	460	0	7.6

Based on the obtained results the optimal mix was selected as a control 2 mix for the second phase of investigation. The second set of mixes were prepared using engine oil to replace chemical admixture in partial substitution of 25%, 50%, 75%, and 100%. More details on these mixes are presented in Table 7. The aforementioned mix M50A50F is labeled CONTROL 2 in the following table. This mix is considered the optimal mix where 100% of sand is replaced.

Table 7: Details of concrete mixes with UEO

Mix Ref.*	Cement	Water	CA 20	CA 10	LF 5	LF 3	Admixture	UEO
M0 (Control 2)	350	120	438	447	457	460	7.6	0
M25	350	120	438	447	457	460	5.7	1.9
M50	350	120	438	447	457	460	3.8	3.8
M75	350	120	438	447	457	460	1.9	5.7
M100	350	120	438	447	457	460	0	7.6

Fig 5: Crushed Limestone Fines <3mm

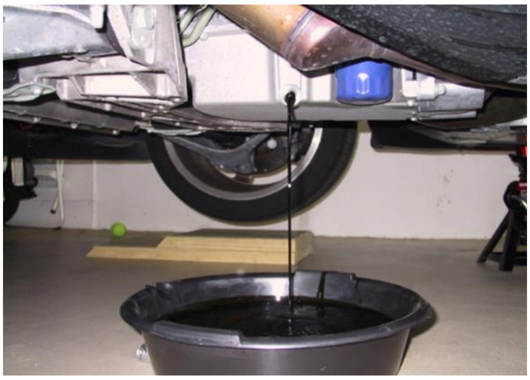

Fig 6: Used Engine Oil

2.2. Testing Methods

Cylindrical specimens of 150x300 mm are used to perform compressive strength (ASTM C39M-20), total water absorption (ASTM C1794), and capillary water absorption tests (ASTM C1585). Before performing these tests the slump test (ASTM C143M-20) was conducted on each mix, at 5 mins, 10 mins, and 30 mins to observe the workability retention of the mix. The slump test is the most commonly used on site, to check the consistency of the freshly mixed concrete (Siddique et al. 2008). The proportion of the raw materials (i.e. cement, aggregate, admixture, and water) per mix, the materials were calculated based on the volume method. Plastic molds were used to cast the concrete specimens. The molds were cleaned and oiled before casting.

The dry materials were introduced to the mixer in the following sequence; coarse aggregates, fine aggregates, and cement. They were initially mixed for two minutes, then water and admixture were added slowly and mixed continuously until a homogenous mix was obtained. When engine oil was used it was added to the mixer while adding water. Compressive strength was recorded at 7, 28, and 56 days and it was rounded to the nearest 0.1 MPa. For more precision, three specimens were tested and an average for the three results was taken. Specimens were cured in air for 24 hours in order to dry. Then, they were cured in water at 20 to 25C in the laboratory. For the capillary test, only one face of the specimen is exposed to water, while in the total absorption test the specimen is completely immersed in water (Kryton, M.2014). Before immersing the specimen in water, its weight is recorded, then after immersing it the weight is measured with respect to time. The capillary test is recorded from 1 min, 3mins, 5 mins, 7 mins, 10 mins, 30 mins, 1 hour, 2hours, 3 hours, 24 hours, and 48 hours. While the total absorption test, the weight is recorded at 10 mins, 20 mins, 30mins, 1 hour, 3 hours, 24 hours, and 48 hours.

Fig.7: Cylindrical Specimen under Compressive Strength Testing

3. RESULTS AND DISCUSSION

3.1. Replacement of Natural Sand by Crushed Limestone

The workability was tested using the slump test in accordance to the standards. All workability test related to the tested mixes were compared to the control one. Slump tests were done at different time intervals as shown below to investigate the retention potential of each mix. Based on the test results in Table 8, it was noticed that the slump decreased slightly, but in reference to the M50A50F mix where coarse and medium sized aggregates percentage was the same as the fines percentage in the mix, the workability of concrete was acceptable in comparison with the other mixes. In general, from the Table 8, that there is no significant difference between slump results of all mixes noting that the desired concrete mix we need is a flowing concrete which can be pumped and finished easily.

Regarding the compressive strength results, where the cement content is 350Kg/ m3, the estimated compressive strength is expected to be around 30 MPa at 28 days. From figure 8, comparing M60A40F and M55A45F with the control mix we can see that at early stage (7 days), we noticed that these mixes yielded a higher compressive strength by 5 MPa than the control mix that gave 27 MPa. So we can understand that limestone fines are contributing in the development of higher early strength. Also M60A40F and M55A45F gave final strength at 56 days approximately higher than the control mix by the same range of 5 MPa that reached 50 MPa at 56 days. Comparing M50A50F with the control mix we can conclude that M50A50F gave higher early strength than the control mix by the same margin of 5 MPa higher than the control mix. Comparing M50A50F with M60A40F and M55A45F, the M50A50F mix reached 48 MPa at 28 days while the first 2 mixes gave a result around 42. The excess presence of limestone fines in M50A50F explains the higher strength reached, since the % of limestone fines was 25% from the total aggregates. This improvement in compressive strength is most probably attributed to the packing phenomenon due to the presence of fines in the concrete mix.

Table 8: Slump Results

Mixes	Slump @ 5mins	@10mins	@ 30mins
Control 1	220mm	190mm	160mm
M60A40F	210mm	175mm	150mm
M55A45F	210mm	180mm	155mm
M50A50F	215mm	185mm	160mm

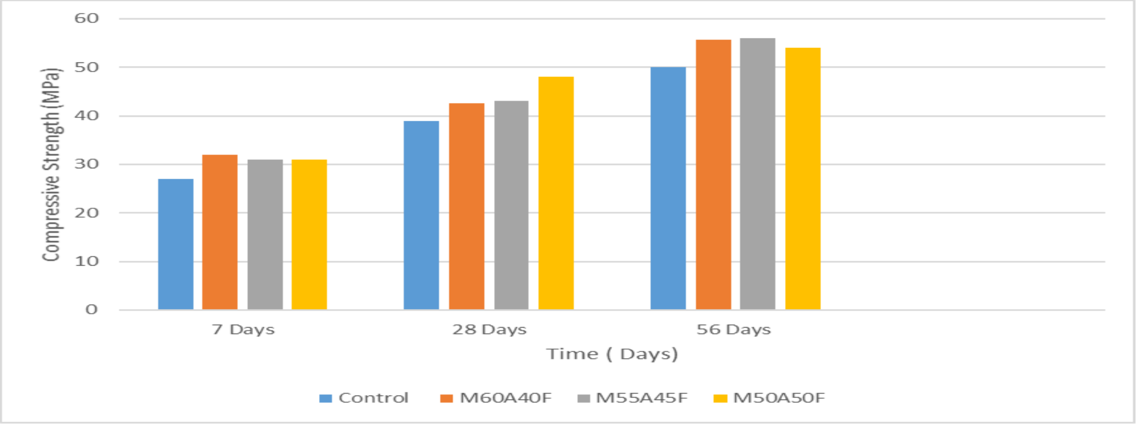

Fig.8: Compressive Strength Results

3.2. Addition of Used Engine Oil

Following the completion of the first phase of the study, and finding the optimum mix where the natural san was successfully and completely replaced by limestone fines with higher, the second phase consisted of using Used Engine Oil in the mix in partial replacement of chemical admixtures. This oil was used in an engine of a truck, the oil is from Total company, and it is a 10W-40 full synthetic oil. It is known that engine oil is a need for every engine operating, and after a period of time this oil needs to be changed so we have a waste product called used engine oil. The Control 2 mix had a very good workability. Comparing the control mix with M25, we can notice that initially the slump was different, and at 30 mins the slump of M25 was lower by 40mm than the Control 2 mix which means that 25% replacement of admixtures by UEO did not highly affect the workability. This means that UEO is not very much flow-able, and it decreases the workability of concrete. Comparing M50 with the control mix, a huge difference in the slump in addition to that the concrete color was tending to be dark grey with some black spot inside. The impressive point here that when removing 50% of the admixtures, at 30 mins the slump was ZERO, due to the effect of UEO and lack of admixture. From Figure 9, observing M75 where 75% of admixtures were replaced, a drop from 15cm to 0 cm in 30 mins, and it was noticeable the rapid drop in 5 mins from 15 cm to 3.5cm. M100, with zero admixtures and 100% UEO completely failed, so we couldn’t take the mix from the mixer since it was completely dry. We faced many difficulties when removing the materials from the mixer. M50, M75, and M100 ended up at 30 mins with a zero slump, which means this mix cannot be used in normal casting, due to the lack of workability and the early setting time. So, this oil causes a drop in slump due to its high viscosity.

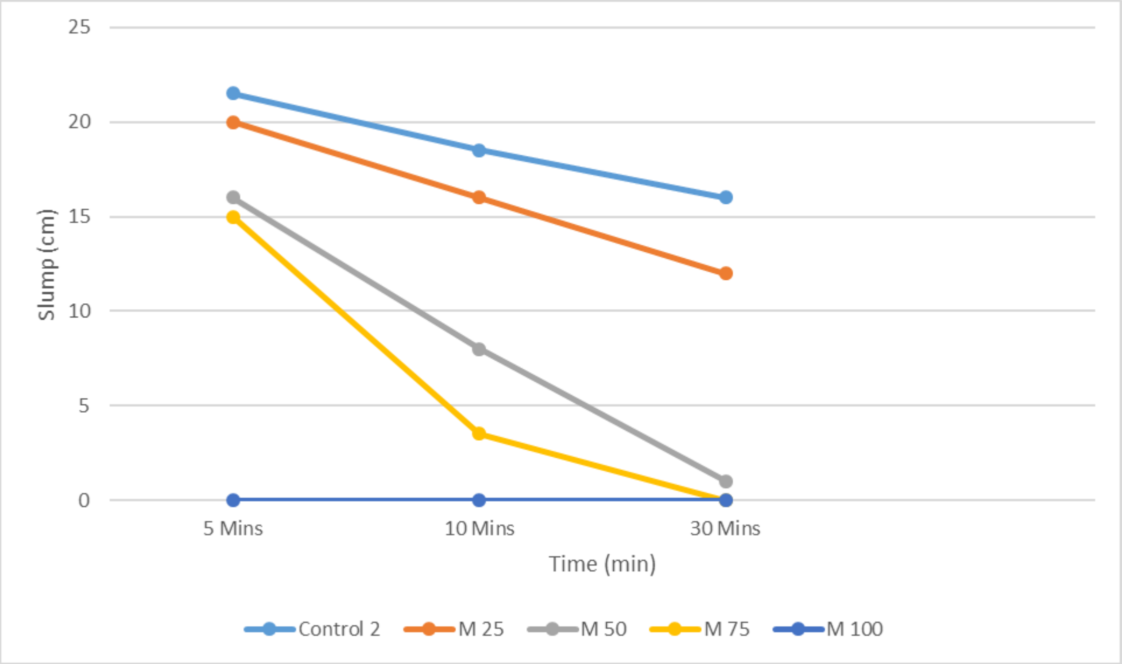

Fig.9: Slump Results

As per the compressive strength results, From Figure 10 shows that comparing M25 with the Control 2 mix, at 7 days they had almost the same strength at 30 MPa which is a satisfactory result, at 28 days both mixes yielded above 40 MPa. Finally, the Control 2 mix yielded higher compressive strength by 10 MPa than M25, actually 10 MPa means 22% higher. This means removing 25% from admixtures and putting UEO instead gave us lower strength but we still have an acceptable strength, actually a very good compressive strength at 42 MPa after 28 days from casting.

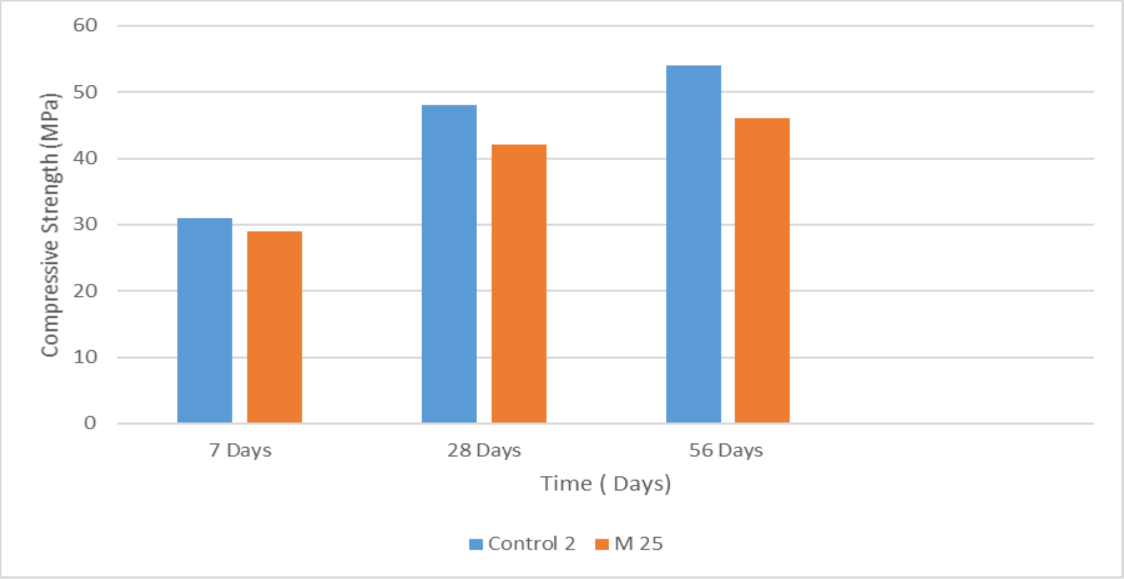

Fig.10: Compressive Strength Results

In Figure 11, when comparing the Control 2 mix with M50 and M75, a considerable drop is observed. At 7 days, the early strength of the Control 2 was 31, while M50 had 22 MPa strength, and M75 yielded 17.5 MPa only. At 28 days the same scenario is present at this stage, Control 2 mix had 48 MPa strength while M50 was 32 MPA, and M75 yielded 22 MPa which is very low.

This means replacing 50% of admixtures by UEO affects the compressive strength clearly with a decrease around 40% which is somehow not acceptable. The same when replacing 75% of admixtures by UEO, the decrease of compressive strength is more than 50%, which clearly shows the important role of the admixture used. So this synthetic oil contains polymer which is also present in the admixture used, this explains the acceptable result in M25.

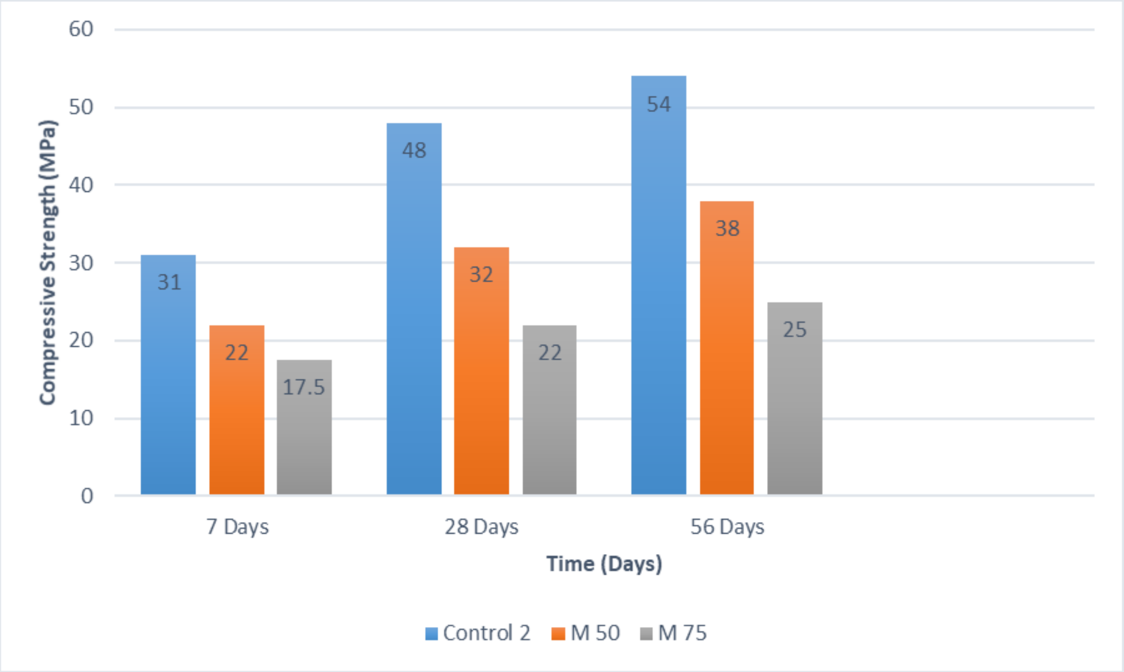

Fig.11: Compressive Strength Results

For the absorption, the specimens are dried in an oven for a specified time and temperature and then removed to cool down slowly. Immediately upon cooling the specimens are weighed. The material is then immersed in water, often 23°C for 24 hours or until equilibrium. Specimens are removed, dry up with a lint free cloth, and weighed. The absorption is measured after several intervals of time. Water absorption is expressed as increase in weight percent.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100

From figure 12, at an early stage; after 1 minute the absorption of the Control mix was 0.31% while Control 2 and M25 had the same percentage around 0.22%. After 1 hour, the absorption of Control mix increases sharply to 1.35%, while Control 2 and M25 increase to 0.39% and 0.35% respectively. After 3 hours the percentage increases more in the Control mix, and here it is noticed that M25 has the lowest absorption percentage. After 48 hours the absorption was 2.3% in the Control mix, 1% for Control 2, and 0.56% for M25. This means that limestone fines play an important role regarding the water absorption percentage as we saw that in presence of limestone fines the absorption percentage decreased. Also after comparing Control 2 with M25 we found that used engine oil can lower the absorption of concrete approximately by half the % of that without UEO.

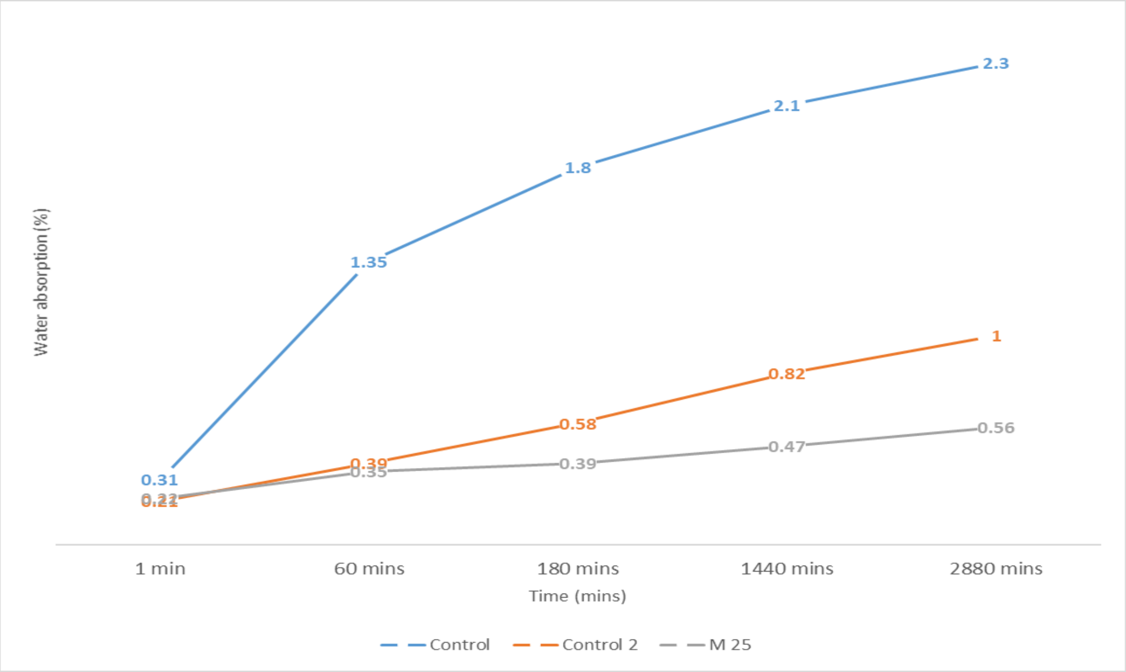

Fig.12: Water Absorption Results

For further analysis, capillary water absorption was performed on M25 to study the effect of UEO, and the results were expected after the water absorption test. In this test only one side of the cylinder is placed in the water, only 5 mm of the cylinder is in contact with water. It is very obvious from figure 13 that the capillary water absorption for M25 was approximately zero. No noticeable change in weight was recorded from the very first minute and after 48 hours which means UEO has a huge effect on such property of concrete which can be used in places where high humidity presents. That’s because of the barrier or water repellant effect that UEO creates in the matrix of concrete which closes all capillaries that water might pass through.

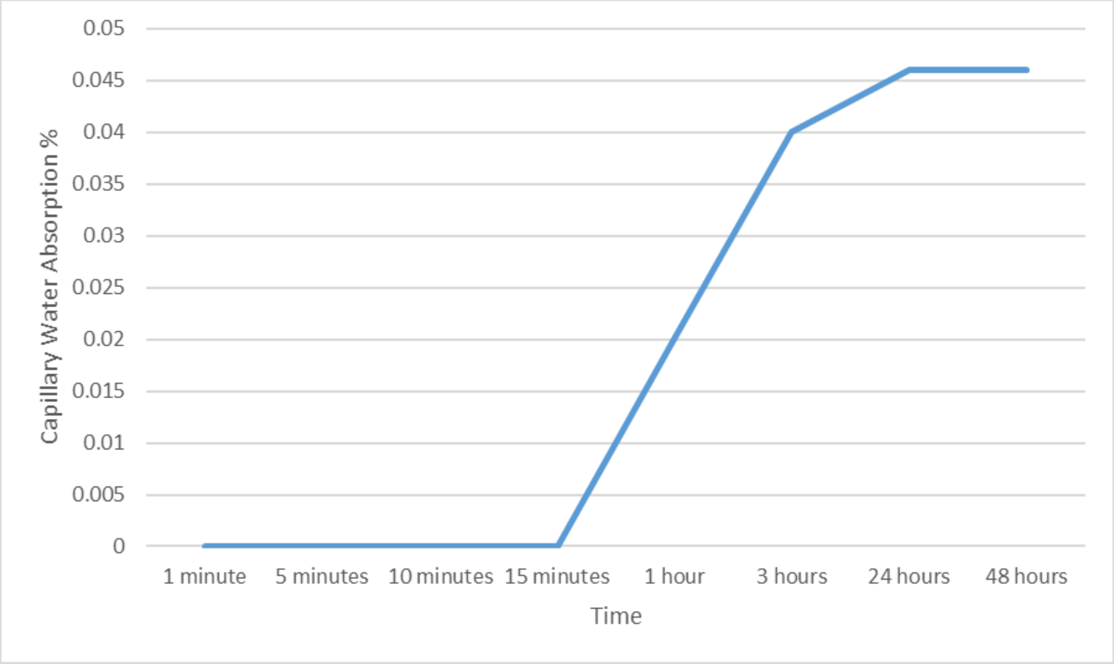

Fig.13: Capillary Water Absorption for M25

4. CONCLUSIONS

The following are the conclusions that can be drawn based on the results of this investigation:

1. Replacing completely natural sand by limestone fines is feasible with an increase in compressive strength, and stability in the workability of concrete.
2. The compressive strength of concrete decreases obviously when admixtures are replaced by Used Engine Oil.
3. Slump of concrete decreases and drops quickly when Used Engine Oil replaces chemical admixtures, because of its high viscosity and incompatibility with the used chemical admixture.
4. Used engine oil creates a barrier system in the microstructure of the concrete matrix which decreases the total and capillary water absorption of concrete by 50%.
5. It was found that, the optimum mix consists of zero natural sand and 100% crushed limestone fines (LF 3). In addition to that, 25% of the admixtures can be replaced by synthetic used engine oil. The compressive strength and workability were reasonable, and the absorption was very low.
6. Further research needs to be conducted to evaluate the impact of UEO on the durability of concrete.

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