UNIVERSIDAD CATÓLICA SANTO TORIBIO DE MOGROVEJO

FACULTAD DE INGENIERÍA

ESCUELA DE INGENIERÍA CIVIL AMBIENTAL

Incorporation of automotive waste oil in plain concrete: effects on physical and mechanical properties

TRABAJO DE INVESTIGACIÓN PARA OPTAR EL GRADO ACADÉMICO DE BACHILLER EN INGENIERÍA CIVIL AMBIENTAL

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Resumen

La investigación eco-amigable con materiales residuales se ha incrementado. Esta investigación pretende evaluar el efecto del Aceite Residual Automotriz (ARA) en las propiedades físicas, mecánicas y químicas del concreto simple. Se utilizó aceite de motor diésel, definiendo los porcentajes de adición de ARA en 0,15%, 0,35%, 0,55% y 0,75% respecto al peso del cemento. La caracterización del ARA contempla el ensayo de Metales por ICP y densidad. Los ensayos en laboratorio para la caracterización del concreto fueron: asentamiento, tiempo de fraguado, exudación, compresión simple y durabilidad por sulfatos. Se comprobó que a mayor porcentaje de ARA se incrementó el asentamiento, el tiempo de fraguado y el agua de exudación. El valor óptimo de adición de ARA es de 0.55%, el cual aumentó un 11% el valor de resistencia a compresión simple y una expansión de 0.054% en el ensayo de durabilidad. Es rentable a diferencia de un aditivo convencional.

Palabras clave: Aceite residual automotriz, aditivo, concreto, contaminación.

Abstract

Eco-friendly research with waste materials has been increasing. This research aims to evaluate the effect of Automotive Residual Oil (ARO) on the physical, mechanical and chemical properties of plain concrete. Diesel engine oil was used, defining ARO addition percentages of 0.15%, 0.35%, 0.55% and 0.75% with respect to the weight of cement. The characterization of the ARO includes the ICP and density test for metals. The laboratory tests for the characterization of the concrete were: slump, setting time, exudation, simple compression and sulfate durability. It was found that the higher the percentage of ARO, the higher the slump, setting time and exudation water. The optimum ARO addition value is 0.55%, which increased the simple compression strength value by 11% and an expansion of 0.054% in the durability test. It is cost effective as opposed to a conventional admixture.

Keywords: Automotive waste oil, additive, concrete, contamination.

Introduction

Lubricants are used in a variety of applications, such as engines, transmissions, hydraulic oils, greases and metalworking fluids. During use, some or all of the lubricant may be consumed by the process, but the remainder may be contaminated with various substances, such as water, metal particles, rust, dirt, carbon, lead and other by-products of combustion or industrial processes (El-Fadel & Khoury, 2001).

Used motor oil, when improperly disposed of through domestic drains or on the ground, can contaminate rivers, streams, aquifers and affect both the environment and public health. Improper disposal of used oil can result in the contamination of groundwater with heavy metals such as lead, magnesium, copper, zinc, chromium, arsenic, etc. Even small amounts of car oil have been found to contaminate large quantities of drinking water or soil, rendering them unusable for agriculture or crop growth for decades. Despite worldwide campaigns to encourage safe disposal of used motor oil, approximately 40% of used motor oil is disposed of illegally and ends up polluting rivers and oceans (Falahi-Ardakani, 1984).

Concrete is an important material in industry and is composed of cement, aggregates, water and admixtures. It has several properties in both fresh and hardened states, fluidity being one of the most important, as it aids in processing and forming. As concrete consumption increases, non-traditional admixtures are used to modify its properties, which are economically beneficial and can have a great economic and technical impact. In addition, wastes are used to replace commercial materials as admixtures (Beddu et al., 2016).

In terms of waste disposal, the construction industry is one of the most convenient and useful industries to prevent or recycle environmental liabilities and waste generated by other industries. The commitment to the planet and its sustainability has led today's professionals to create alternatives to optimize and value waste (Beddu et al., 2016).

Residual auto oil presents certain characteristics in its internal structure that promise to improve the properties of concrete in its fresh state, such as slump, without altering its properties in the hardened state. Using it as a chemical softener and retarder of in hot climates (Montilla et al., 2019).

A recent study determined that the optimum residual dosage was 0.13%, the compressive strength values obtained using automotive residual oil were 9%, 13% and 8% higher than the strength values of the control samples at 7, 14 and 28 days; in addition, the average slump (slump) was 6.25 inches compared to 5.67 inches for the control mixture (Montilla et al., 2019).

Therefore, the general objective of this study was to evaluate the properties of fresh concrete, such as slump, setting time and exudation, and concrete in hardened state such as compressive and tensile strength for a strength of 210 kg/cm2 by adding diesel engine waste oil at 0.15%, 0.35 %, 0.55% and 0.75%. The properties of the concrete with the addition of ARO were compared with the standard concrete without the addition of ARO, in order to determine if there is an optimum percentage to be worked later on site.

Fig. 1 - a) Automotive waste oil collected for research (ARO), b) ARO supplier oil change center

Source: Author

Methodology

Materials

In this study, Type I Qhuna Portland Cement was used (its use does not require special specifications) that complied with the requirements of NTP 334.009; fine and coarse aggregate from quarries in the department of Lambayeque that comply with the requirements of ITINTEC 400.037 was also used; the residual car oil used was selected from vehicles with diesel engines, collected by 3 formal oil centers.

The amount of metallic particles according to the Induced Plasma Spectrometer - ICP test, in accordance with ASTM D 7111 standards were as follows:

Table 1 – Amount of metals in Residual Auto Oil

Parameter	Metales por ICP	Unidad
Aluminum	<0.50	ppm
Barium	<0.50	ppm

Calcium	441.60	ppm
Chromium	1.23	ppm
Cobalt	<0.50	ppm
Copper	0.71	ppm
Iron	49.95	ppm
Lithium	<0.50	ppm
Lead	3.26	ppm
Magnesium	135.13	ppm
Manganese	1.04	ppm
Molybdenum	6.20	ppm
Nickel	<0.50	ppm
Phosphorus	274.04	ppm
Potassium	<0.50	ppm
Sodium	<0.50	ppm
Silicon	1.06	ppm
Silver	<0.50	ppm
Strontium	<0.50	ppm
Tin	<0.50	ppm
Titanium	<0.50	ppm
Vanadium	<0.50	ppm
Zinc	337.56	ppm

Source: Slab Perú S.A.C.

Concrete Mixes

A comprehensive research plan was designed to evaluate the flowability, setting and exudation time, setting time and unit weight of fresh concrete mixtures. In addition, the characteristics of hardened concrete, such as compressive strength, modulus of elasticity and tensile strength at different curing ages (7, and 28 days) were studied. In total, 5 concrete mixtures were prepared with different proportions of materials, which are described in detail in Table 2

Table 2- Concrete mix details(kg/m3)

Proportion	Control Mix	Mix with 0.15% (M1)	Mix with 0.35% (M2)	Mix with 0.55% (M3)	Mix with 0.75% (M4)
Cement	385.88	393.73	344.59	329.44	327.44
ARO	-	0.469	0.792	1.115	1.446
Fine aggregate	736.26	736.26	736.26	736.26	736.26
Thick aggregate	978.13	978.13	978.13	978.13	978.13
Water	222.9	222.9	222.9	222.9	222.9

Source: Author

Casting and Curing

The preparation of the concrete was carried out in a mixer of 9 ft3 of capacity; it was started by mixing the fine and coarse aggregate together with half of the total water of the mixture, 1 minute later the cement was incorporated; before adding the residual auto oil (previously measured in a glass test tube) it was mixed in the other half of water to then be poured to the dry ingredients in the mixer. It was mixed for 2 more minutes to obtain a homogeneous mass.

Standard procedures established by ASTM C31 were followed throughout the pouring process. To prepare the specimens, they were filled in three layers with applications of 25 bars and 15 compactions per layer. After 24 hours, the specimen was removed from the mold to be cured, using the immersion method, where specimens are immersed in a pool of water. Ten specimens were prepared for compressive strength testing, 10 specimens for tensile strength testing and 10 specimens for modulus of elasticity testing for each percentage addition of Residual Automotive Oil. The dimensions of the concrete specimens were 15 cm in diameter and 30 cm in height. They were then tested at 7 and 28 days.

Testing Procedure

Slump Test

The slump test was performed in accordance with the standard procedures specified in ASTM C143, a test used to evaluate the flowability or workability of fresh concrete mixtures. The process consists of pouring the concrete mix in three layers in a truncated cone (Abrams cone) and compacting each layer with a rod 25 times. The cone is then lifted vertically and the difference in height between the top of the cone and the displaced axis of the dropped or settled concrete sample is measured. The difference in height measurement is used as an indicator of the consistency of the concrete mix.

Setting Time Test

The setting time test was performed according to the standard procedures specified in ASTM C403. The mortar was obtained from the concrete mix by passing it through the standard #4 sieve in order to eliminate the coarse aggregate. The mortar was poured into the mold to rod and strike the mixture 25 and 15 times, respectively. Before starting the test, it was left to stand for a period of 4 hours. Finally, penetration with the needles was performed every 30 minutes until the sample had set, reaching 4000 psi of applied force.

Exudation Test

The exudation test was performed in accordance with the standard procedures specified in ASTM C232. The mold was filled in 3 layers, however, the last layer was thinner to leave a space of not less than 1" in. The mold was inclined to favor the bleeding of the concrete, using a syringe the reading of the exuded water was recorded every 10 minutes for the first 40 minutes; then it was recorded every 30 minutes until the mixture stopped bleeding.

Unit Weight Test

The unit weight test was performed according to the standard procedures specified in ASTM C138. Before starting, the weight of the mold was recorded, then the concrete was poured in 3 layers to rod and strike the mix 25 and 15 times respectively. Finally, the weight of the mold plus the fresh concrete mix is read, the subtraction of both between the volume of the mold will result in the unit weight of the concrete.

Temperature Test

The temperature test was performed in accordance with the standard procedures specified in ASTM C1064. In a mold the concrete was poured in 3 layers to rod and tap the mixture 25 and 15 times respectively; the thermometer was inserted approximately 3 inches into the specimen and waited 2 to 5 minutes until the temperature stabilized to finally take the reading.

Compressive strength test

The compressive strength test was performed in accordance with the standard procedures specified in ASTM C39. To perform this test, the concrete specimen was removed from the curing tank and waited until it was superficially dry. Finally, the specimen was placed on the shaft of the testing machine and the constant load was gradually applied until the moment of failure of the specimen was observed.

Modulus of Elasticity Test

The modulus of elasticity test was performed according to the standard procedures specified in ASTM C469. The specimen was attached to the longitudinal load measuring device so that the axis of the specimen is aligned with the center of the testing machine. The load was gradually applied until it reaches 50 ppm, the load and longitudinal deformation were recorded. In addition, reading is taken when the load reaches 40% of the maximum load.

Indirect Tensile Strength Test

The modulus of elasticity test was performed in accordance with the standard procedures specified in ASTM C496. To perform this test, the concrete sample was removed from the curing tank and waited until it was superficially dry. The sample was placed transversally, making its axis coincide with that of the testing machine, and finally the constant load was applied to take a reading of the breaking load.

Results and discussion

Slump Test

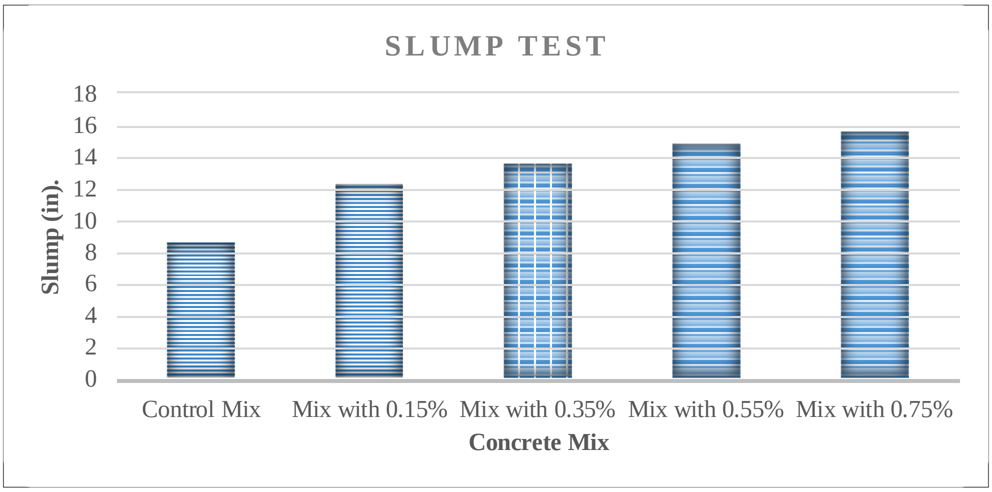
In the slump test, the highest result obtained was for the mixture with 0.75% residual auto oil with a value of 6.1 inches, in fact, all the concrete mixtures with the addition of ARO exceed the slump of the control sample that was initially designed for a slump of 3 inches. It can be stated that the increase in slump is directly proportional to the slump obtained. In a similar study (Noori et al., 2013), it was evidenced that, for the same addition of ARO at 0.75%, a slump of 3.03 inches was obtained, being 49% lower than the result obtained in this study.

Table 3 – Slump test results

Concrete mix	Slump (cm)
Control Mix	8.5
Mix with 0.15% (M1)	12.2
Mix with 0.35% (M2)	13.5
Mix with 0.55% (M3)	14.7
Mix with 0.75% (M4)	15.5

Source: Author

Graph 1 – Slump Variation



Source: Author

Setting Time Test

The setting time for the standard sample was 91 minutes, the additions of residual auto oil increased the setting time of the concrete mixes; the longest setting time was 135 minutes for the addition of 0.75%; this is because the higher the amount of ARO the mix was much more plastic and liquid making the setting time longer.

Table 4 – Setting time test results

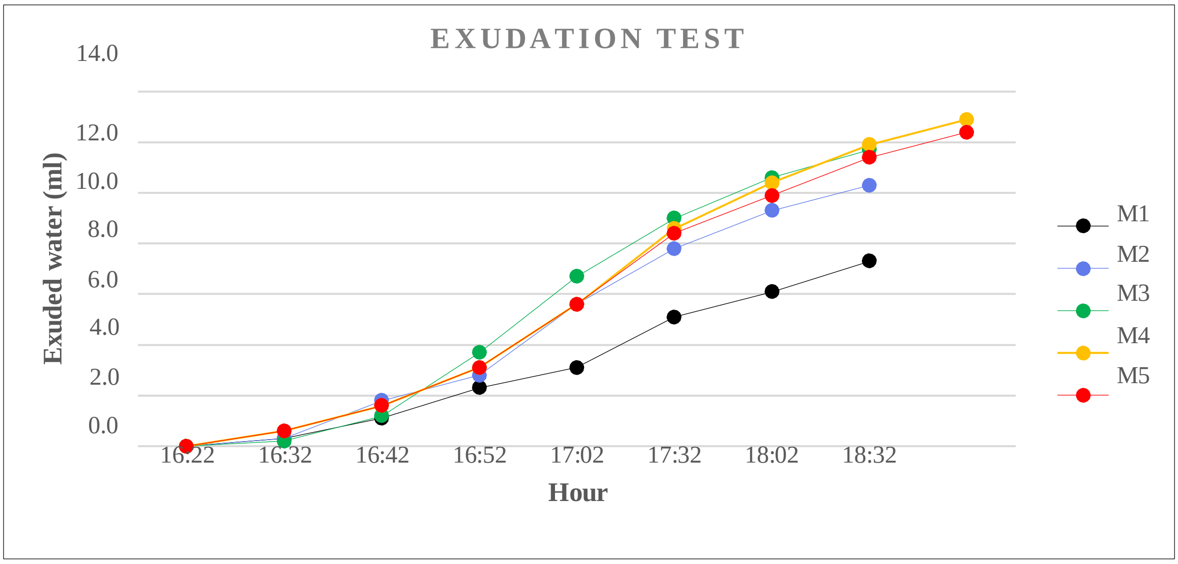
Concrete mix	Initial set (min)	Initial set (min)	Setting (min)
Control Mix	259	350	91
Mix with 0.15% (M1)	254	362	108
Mix with 0.35% (M2)	262	377	115
Mix with 0.55% (M3)	275	405	130
Mix with 0.75% (M4)	305	440	135

Source: Author

Exudation Test

The exudation or bleeding of the concrete showed increasing values, i.e., the percentage of oil was directly proportional to the value of the exuded water, since the mixture with a greater amount of oil had a more fluid consistency, this is due to the fact that in a more liquid mixture the coarse particles are segregated, giving way to the fines to move towards the surface, a phenomenon produced by the difference in densities.

Graph 2 – Exudation test results



Source: Author

Unit weight test

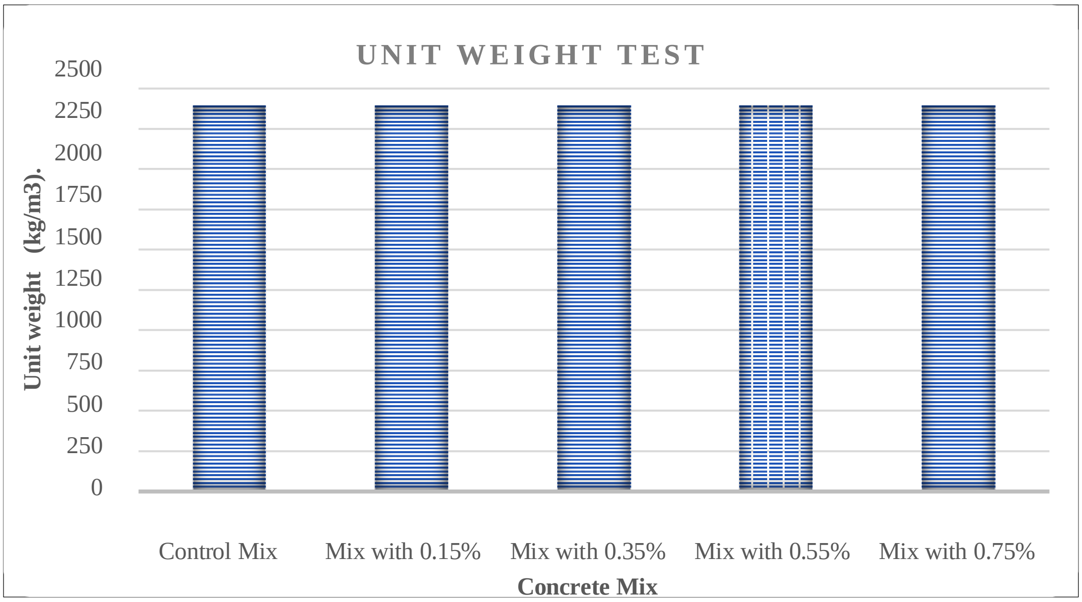
The unit weight recorded with the highest value was that of the standard concrete with 2394.07 kg/m3, henceforth for the rest of the samples with the addition of auto oil the value is reduced, this because the density of the oil is lower than the density of water.

Table 5 – Unit weight test results

Concrete mix	Mold weight (kg)	Mold weight + Concrete weight (kg)	Unit weight (kg/m3)
Control Mix	0.380	13.072	2394.07
Mix with 0.15%	0.38	13.067	2393.12
Mix with 0.35%	0.38	13.069	2393.50
Mix with 0.55%	0.39	13.078	2393.31
Mix with 0.75%	0.38	13.07	2393.69

Source: Author

Graph 3 - Unit Weight Variation



Source: Author

Temperature Test

The highest temperature recorded is that of the mixture with 0.15% residual motor oil at 23.1 °C. It should be noted that the temperatures recorded do not maintain a pattern of increase or decrease, since they vary in their results. It is important to mention that the environment where the temperature was taken was free of any factor that could have altered the result, and it also depends on the caloric contribution of the ingredients.

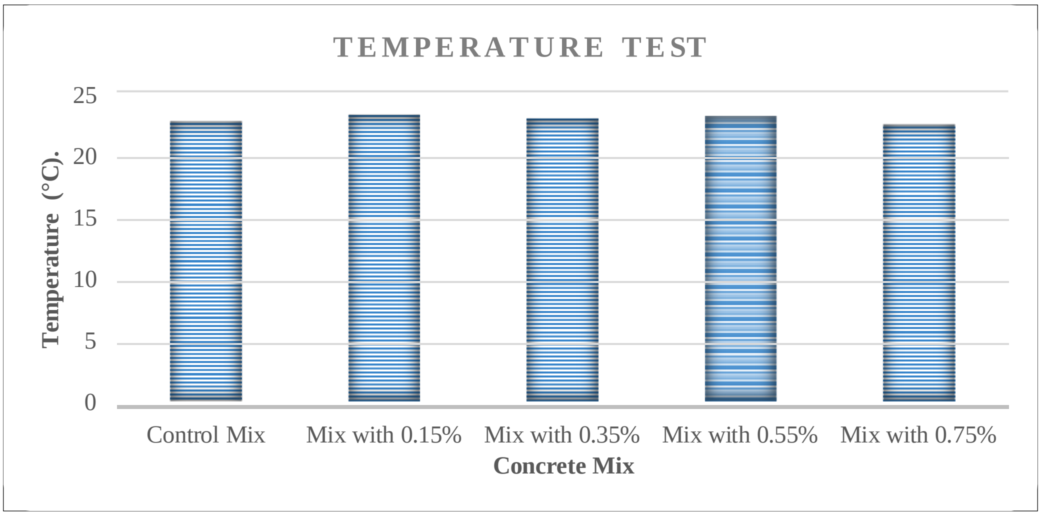
It can be affirmed that the temperature value is within the permitted range, since it does not exceed 35°C.

Table 6 – Temperature test results

Concrete mix	Temperature (°C)
Control Mix	22.6
Mix with 0.15% (M1)	23.1
Mix with 0.35% (M2)	22.8
Mix with 0.55% (M3)	23.0
Mix with 0.75% (M4)	22.3

Source: Author

Graph 4 - Temperature Variation



Source: Author

Compressive strength test

The highest compressive strength was the mixture with 0.55% waste car oil addition with 274.4 kg/cm2, the additions with 0.15% and 0.35% diesel engine oil did not exceed the standard sample, however the standard sample did efficiently exceed the compressive strength of 210 kg/cm2 for which it was designed. A research (Alsadey, 2018) used a value similar to the one used in this research, where the 0.5% used engine oil obtained a resistance of 234.5

kg/cm2, in addition, (Giridhar, 2017) worked with the same percentage of 0.5% obtained a compressive strength of 318.6 kg/cm2.

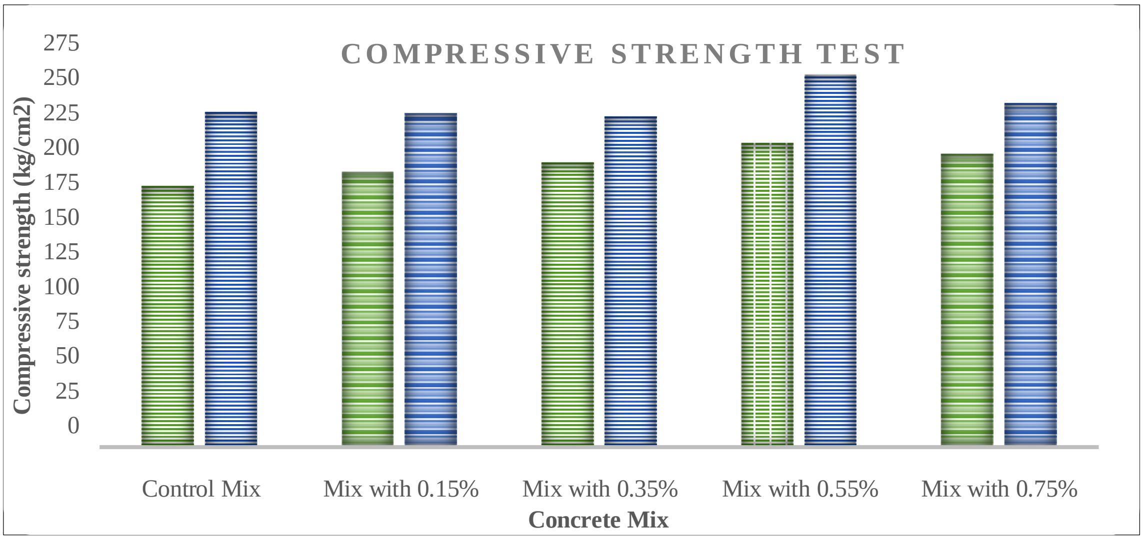
It is also highlighted that the percentage of 0.75% of residual car oil exceeded the design strength and the strength of the standard sample with a strength of 253.4 kg/cm2, another study using the same addition of used oil shows the comparison in terms of compressive strength employing new and used car oil, where the used engine oil at 28 days obtained 2.5% more than the sample with new engine oil. It is important to mention that the laboratory conditions were more controlled, therefore, the weighing, mixing, pouring, curing and testing of the samples had minimal margins of error.

Table 7 – Compressive Strength Test Results

Concrete mix	7 days (kg/cm^2)	28 days (kg/cm^2)
Control Mix	192.3	247.2
Mix with 0.15% (M1)	203.1	245.9
Mix with 0.35% (M2)	210.0	243.6
Mix with 0.55% (M3)	223.9	274.4
Mix with 0.75% (M4)	216.3	253.4

Source: Author

Graph 5 - Compressive Strength Variation



Source: Author

Modulus of Elasticity Test

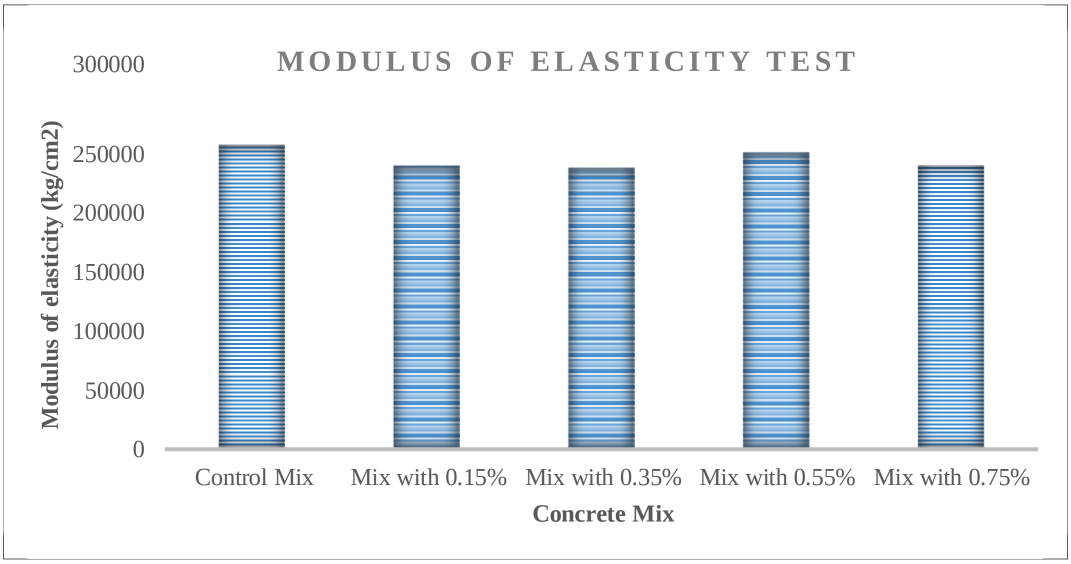
The highest modulus of elasticity was that of the control sample with 255585.1 kg/cm2, since it is the densest sample of the research, the second highest value was the mixture with 0.55% of residual car oil with 248645.0 kg/cm2, addition that also obtained the highest compressive strength, this may be a product of the quality of the ingredients of the concrete and curing of the specimen.

Table 8 - Modulus of Elasticity Test Results

Concrete mix	28 days (kg/cm^2)
Control Mix	255585.1
Mix with 0.15% (M1)	237540.5
Mix with 0.35% (M2)	236269.9
Mix with 0.55% (M3)	248645.0
Mix with 0.75% (M4)	238370.2

Source: Author

Graph 6 - Modulus of Elasticity Variation



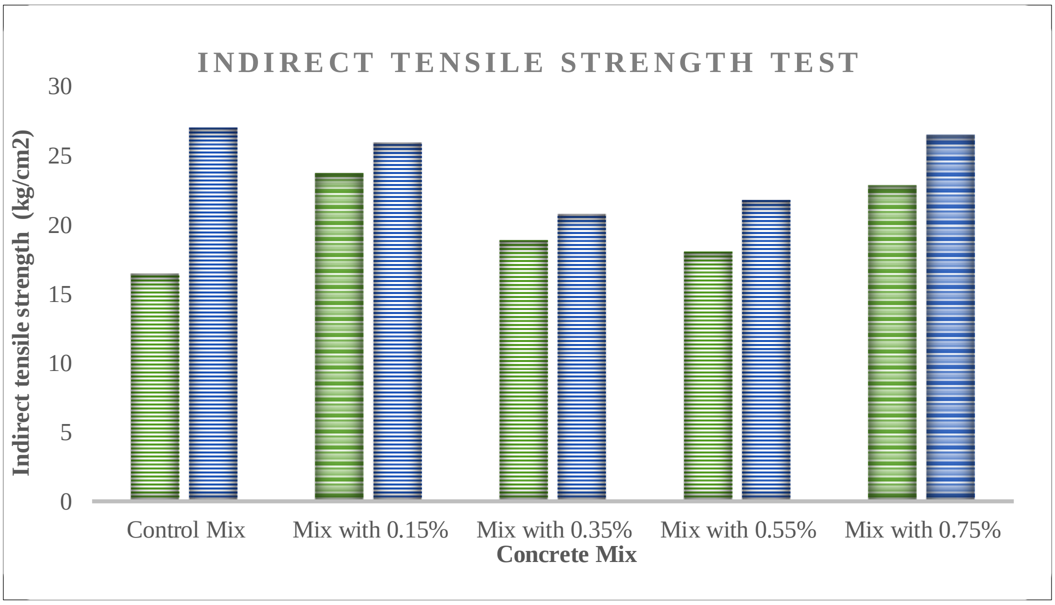
Source: Author

Indirect Tensile Resistance Test

The tensile strength had particular results, at 7 days the control sample had the lowest value with 16.3 kg/cm2, which was surpassed by the addition of 0.15% oil with 23.5 kg/cm2, followed by the addition of 0.75% with 22.7 kg/cm2. Later at 28 days, the standard sample had a sudden increase in its result with 26.8 kg/cm2 ; a similar result was obtained by the addition of 0.75% oil with 26.3 kg/cm2 , followed by the 0.15% addition with 25.7 kg/cm2 . The 0.35% and 0.55% additions had the lowest values at 7 and 28 days.

(Giridhar, 2017) in his research works with used car oil at 0.5% and at 28 days obtained at a resistance of 20.08 kg/cm2, in this case the value worked in the research exceeds this result with 21.6 kg/cm2.

Graph 7 - Indirect Tensile Strength Test Results



Source: Author

Conclusions

Automotive Residual Oil (ARO) is a hydrocarbon that contains heavy metals and other chemical compounds from engine combustion and has a higher viscosity due to the presence of residues or particles from engine wear, making it conveniently useful for micro-adhesion in simple concrete mixes.

In the fresh state, ARO tends to improve the workability (slump) of the concrete, as well as increase the setting time and the amount of water exuded from the mix. Therefore, it could be used as a retarding admixture in hot climates. As for the unit weight, it tended to decrease since the oil has a lower density than water; with respect to temperature, there was no major pattern of change; it remained variable according to environmental conditions.

In the hardened state, an 11% increase in resistance was observed with the addition of 0.55%, likewise, the addition of 0.75% also showed an increase in resistance of 2.5% with respect to the control sample. Regarding the modulus of elasticity test, the 0.55% addition obtained the highest value but did not exceed the modulus of elasticity of the standard sample with 255585. 1 kg/cm2.

The residual automotive oil should be incorporated into the concrete, previously activated in water, since this way it has a better behavior in terms of its physical and mechanical properties.

Acknowledgments

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References

- ✓ ASTM C31/C31M. (2008). Standard Practice for Preparation and Curing of Concrete Test Specimens on Site.
- ✓ ASTM C143/C143M. (2010). Standard Test Method for Slump of Hydraulic- Cement Concrete.
- ✓ ASTM C232/C232M. (2009). Standard Test Methods for Bleeding of Concrete.
- ✓ ASTM C138/C138M. (2017). Standard Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete.
- ✓ ASTM C1064/C1064M. (2012). Standard Test Method for Temperature of Freshly Mixed Hydraulic- Cement Concrete.
- ✓ ASTM C403/C403M. (1999). Standard Test Method for Time of Setting of Concrete Mixtures by Penetration.
- ✓ ASTM C469. (2002). Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression.
- ✓ ASTM C39. Test Method. Determination of Compressive Stress of Cylindrical Specimens.
- ✓ ASTM C496. Test method. Determination of Indirect Tensile Strength of Cylindrical Concrete Specimens.
- ✓ Alsadey, S. (2018). Effects of Used Engine Oil as Chemical Admixture in Concrete. In International Journal of Energy and Sustainable Development (Vol. 3, Issue 2). http://www.aiscience.org/journal/ijesdhttp://creativecommons.org/licenses/by/4.0/

- ✓ Beddu, S., Shafiq, N., Nuruddin, M., Kamal, N., & Sadon, S. (2016). Effects of Used Engine Oil as an Admixture in Concrete Durability. British Journal of Applied Science & Technology, 15(6), 1–10. https://doi.org/10.9734/bjast/2016/20738
- ✓ El-Fadel, M., & Khoury, R. (2001). Strategies for vehicle waste-oil management: a case study. In Resources, Conservation and Recycling (Vol. 33). www.elsevier.com/locate/resconrec
- ✓ Falahi-Ardakani, A. (1984). Contamination of Environment with Heavy Metals Emitted from Automotives. In ECOTOXICOLOCY AND ENVIRONMENTAL SAFETY (Vol. 8).
- ✓ Giridhar, V. (2017). IMPACT OF WASTE ENGINE OIL IN CONCRETE COMPOSITION (Issue 4).
- ✓ Montilla, T. B., Mogollón, C. A., Gómez, J. D. A., & Arbolaez, I. A. (2019). Automotive waste oil as an additive in concrete mixtures: Its use is feasible. Revista Materia, 24(2). https://doi.org/10.1590/s1517-707620190002.0658