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Influence of superficially oxidized steel shavings on the mechanical properties of concrete

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

AUTOR

Victor Jesus Chozo Martinez

ASESOR

Carlos Rafael Tafur Jimenez

https://orcid.org/0000-0003-0119-8234

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Resumen

El objetivo de la presente investigación fue evaluar el comportamiento mecánico del concreto adicionado con virutas de acero oxidadas y concreto simple. Las virutas de acero oxidadas se cortaron en medidas longitudinales de 1”, 1.5” y 2” para ser adicionadas al concreto en 2%, 3% y 4% respecto al peso del cemento. Para tal fin, se indujo a las virutas de acero a un proceso de sumersión en agua potable durante 3h, posteriormente se colocaron a temperatura de ambiente para su secado natural durante 48h, lo cual finalmente se obtuvo un grado de oxidación de 1% y 2%, además, se generó un aspecto rugoso en su superficie que favoreció la adherencia entre esta y los componentes del concreto. Los resultados indican que las virutas de acero oxidadas de 1” al 2% lograron un mejor comportamiento en las propiedades mecánicas del concreto, en resistencia a compresión generó un incremento hasta de 17.27% y en resistencia a tracción indirecta hasta un 15%. Se identifico, que los mejores resultados del ensayo a flexión en vigas se dieron con la adición de virutas de 1” al 4% incremento hasta un 39.36% respecto a la muestra patrón. Además, las virutas de acero superficialmente oxidadas es una alternativa frente a las fibras de acero comerciales, lo cual tiene un costo elevado.

Palabras claves: Fibras, virutas de acero, fibras oxidadas, concreto con fibras.

Abstract

The objective of the present investigation was to evaluate the mechanical behavior of the concrete added with oxidized steel shavings and simple concrete. The rusty steel chips were cut in lengths of 1”, 1.5” and 2” to be added to the concrete at 2%, 3% and 4% with respect to the weight of the cement. For this purpose, the steel shavings were induced to a process of immersion in drinking water for 3h, then they were placed at room temperature for natural drying for 48h, which finally obtained a degree of oxidation of 1% and 2. %, in addition, a rough appearance was generated on its surface that favored the adhesion between it and the concrete components. The results indicate that the oxidized steel shavings of 1" at 2% achieved a better behavior in the mechanical properties of the concrete, in compressive strength it generated an increase of up to 17.27% and in indirect tensile strength up to 15 %. It was identified that the best results of the bending test in beams occurred with the addition of 1" shavings at 4%, an increase of up to 39.36% compared to the standard sample. In addition, superficially oxidized steel swarf is an alternative to commercial steel fibers, which is expensive.

Keywords: Fibers, steel shavings, fiber oxidized, concrete fibers.

Introduction

Concrete is one of the materials that has been used since Hellenic periods, initially with the use of rudimentary natural cements and characterized by its high resistance to compressive stresses [1]. However, it has presented deficiencies in the face of plastic contraction, traction, and bending efforts [2, 3, 4]. A clear example is simple concrete pavements, which have been vulnerable to different pathologies caused by increased traffic loads or climatic variations, consequently generating a short period of useful service time, in addition to interruptions in service. service [5]. Given this, the construction sector has been innovating in materials technology to counteract the deficiencies that occur in the different simple concrete structures, which is why, in recent years, the need has been seen to employ additions such as the use of industrial or recycled fibers. The latter is an alternative for the use of industrially generated by-products, being also an eco-friendly solution to the environment in the face of the increase in global pollution where the industrial sector has been one of the main collaborators [6, 7]. In this sense, research on the use of steel shavings as a component to produce fibrous concrete demonstrates the improvement in its mechanical properties, in addition to counteracting cracking due to plastic contraction [8,9].

Steel shavings are secondary materials produced by the wear of different metal parts, which the lathe industry produces in large quantities annually, a clear example is the country of India, producing approximately 20 tons. Likewise, it is important to consider that relatively low costs are estimated to be obtained [10,11].

It is important to know the adhesion that this type of addition may have with the concrete components since the results that we can obtain from the physical and mechanical properties directly depend on this, in addition, the different studies indicate that improving the smooth to rough appearance of the Consequently, fibers cause an increase in the mechanical properties of concrete, such as tensile and flexural resistance. [12]

However, the inclusion of this specific type within national regulations, the use and industrialization of oxidized steel shavings for use in concrete are limited.

Methodology

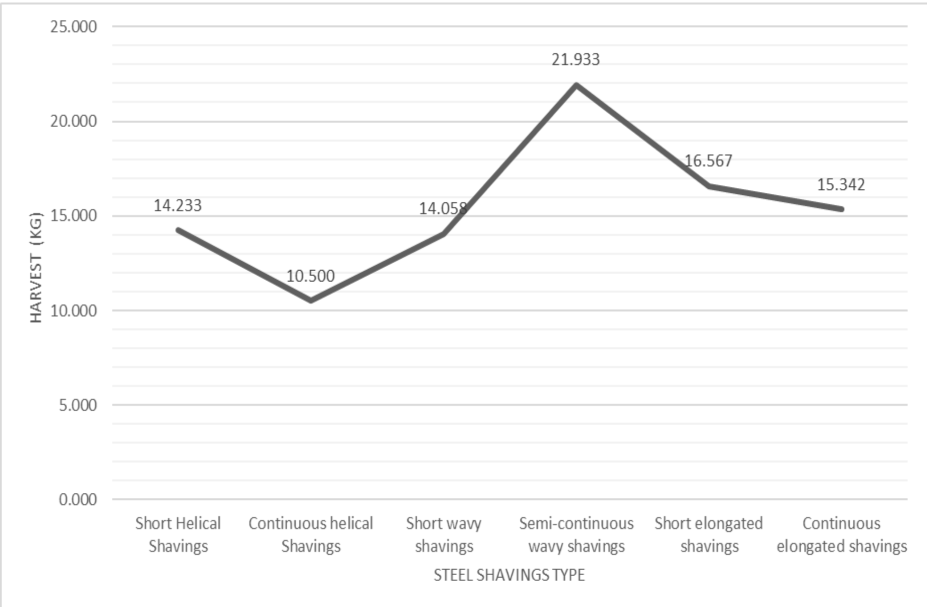
Materials

The research was carried out experimentally in the laboratory. To analyze the rheological characteristics of the concrete added with oxidized steel shavings, aggregates from the Tres Tomas and Pátapo quarries, located in the Lambayeque region, were used. In this way, tests were carried out on quarry material, considering the permissible limits of gradation considered in NTP 400.012 - NTP 400.037.

In addition, type I cement (general use) was available, its specific weight being 3130 kg/cm^2, and it did not present any type of addition that could influence the results.

On the other hand, it should be noted that the steel shavings were collected from lathe manufacturing companies, located in the José Leonardo Ortiz district, belonging to the Chiclayo province, Lambayeque region. In this way, the characterization of these was carried out for a better management and collection control, having a total production of 92 kg per week. However, after the analysis, only elongated and semi-corrugated chips with a thickness > 0.3 mm were used (See Fig. 1).

Figure 1. Volumetric amounts of steel shavings collected.



Source: Authors.

Table I shows the lengths and percentages of addition of oxidized steel shavings used for the development of the investigation.

Table 1. Longitudinal characteristics and improved percentage of oxidized steel shavings.

LENGTH OF OXIDIZED STEEL SHAVINGS	% Regarding the weight of cement
1”	2%, 3% y 4%
1 ½”	2%, 3% y 4%
2”	2%, 3% y 4%

Source: Authors

Surface modification of steel shavings

One of the most important aspects of the research was to modify the smooth surface of steel shavings by oxidation surface treatment. This consists of storing steel shavings in sealed boxes, in order not to be contaminated. Subsequently, the selection of semi-undulated and elongated shavings with a thickness greater than 0.3 mm was carried out, which allows their handling with greater simplicity, finally they were manually cut. In previous studies, immersion in water was induced for 3h, 6h, 9h and 12h with a natural drying exposure of 24h, 48h and 72h, which surface oxidation results were evidenced by immersing the shavings for a period of 3h with a 48h natural drying exposure. In addition, 10 units of steel shavings were randomly selected, recording the diameter, length, and weights (pre - post treatment) to evaluate the % oxidation and that this does not exceed the permissible limit of 94% of its diameter [13].

Figure 2 shows on the left margin the steel shavings in their normal state, while on the right margin the state of the shavings after finishing the surface oxidation treatment is observed.

Figure 2. Pre and post - surface treatment of oxidation to steel shavings.

Source: Authors

Once the laboratory tests of the aggregates and oxidized steel shavings were completed, the mix design was carried out using the ACI 211 methodology, considering f'c of 280 kg/cm^2. To contrast the hypothesis raised in the investigation, the production of standard sample concrete and concrete added with oxidized steel shavings was carried out, considering Table I.

Table 2 shows the characterization of the aggregates used to prepare the mix design.

Table 2. Coarse and fine aggregate properties.

AGGREGATE TEST	Fine aggregate	Coarse Aggregate	Unit
Nominal maximum size	-	3/4"	pulg.
Dry Loose Unit Weight	1.54451	1.45047	g/cm^3
Dry compacted unit weight	1.78429	1.65548	g/cm^3
Specific weight of dry mass	2.53448	2.53608	kg/cm^3
Moisture content	2.75000	0.32017	%
Absorption content	0.78613	0.60976	%
Fineness modulus	2.42	-	

Source: Authors.

Specimen Preparation

Subsequently, the tests in plastic state were evaluated. To determine the slump of the concrete added with oxidized steel shavings, the Abrams cone was used considering the ASTM C143 standard. Likewise, the cracking potential test was developed and determined by ASTM C1579.

Cylindrical 4"x8" specimens were manufactured to obtain compressive strength data and indirect traction during 7 and 28 days. Simultaneously, 15x15x55 cm prismatic specimens were made, then following NTP 339.078 they were tested for flexion. Finally, 6"x12" cylindrical specimens were used, which were tested to obtain the modulus of elasticity.

Figure 3 shows some study samples that were tested in indirect compression and traction.

Figure 3. 4"x8" cylindrical specimens.

Source: Authors.

The indirect compression and tensile failures of the specimens can be analyzed in figure 4, on the left and right margin, respectively.

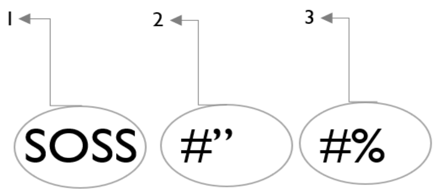
Figure 4. Compressive and indirect tensile failures.

Source: Authors.

Nomenclature

For the registration of the study samples, the nomenclature of figure 5 was used.

Figure 5. Nomenclature of study samples.



Source: Authors.

Which corresponds:

1: Sample of oxidized steel shavings

2: Length oxidized steel shavings

3: Percentage oxidized steel shavings

Research Rationale

The different review literatures about concrete added with steel shavings, aluminum shavings or recycled shavings have not shown a treatment that improves the smooth appearance that these have when they are acquired, and consequently obtain favorable results in mechanical properties. In addition, the use of this type of waste emerges as an environmentally sustainable alternative.

Results

Properties of concrete in plastic state

Table 3 shows the settlement reached by each one of the addition percentages, which did not show variability with respect to the standard sample. This is since short lengths were taken and the treatment that was carried out on the oxidized steel shavings, which would cause each of these to be distributed evenly throughout the concrete mix.

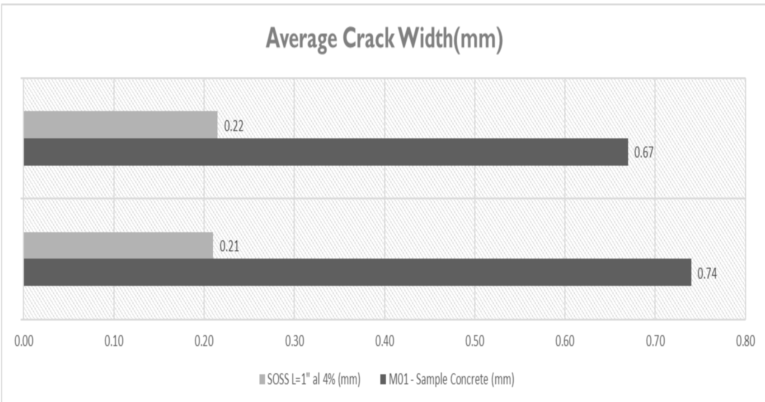
Table 3. Properties of concrete in plastic state.

CONCRETE TYPE	Oxidized steel shavings		Slump (in)
	Length (cm)	Percentage (%)	
Sample Concrete	-	-	3.0"
Concrete + Oxidized steel shavings	SOSS1" al 2%	2.00%	3.2"
	SOSS 1" al 3%	3.00%	3.0"
	SOSS 1" al 4%	4.00%	3.0"
	SOSS 1 ½" al 2%	2.00%	3.0"
	SOSS 1 ½" al 3%	3.00%	3.0"
	SOSS 1 ½" al 4%	4.00%	3.0"
	SOSS 2" al 2%	2.00%	3.1"
	SOSS 2" al 3%	3.00%	3.0"
	SOSS 2" al 4%	4.00%	3.0"

Source: Authors.

In the cracking potential test, climatic conditions that induce cracking of concrete slabs in their plastic state were adapted, with a high temperature of 38 °C, wind speed of 7 m/s and relative humidity of 30. In figure 6, the results determined the average width of 0.71 mm and 0.215 for the standard sample of simple concrete and concrete added SOSS L=1" at 4%.

Figura 6. Average crack width obtained from the crack potential test.

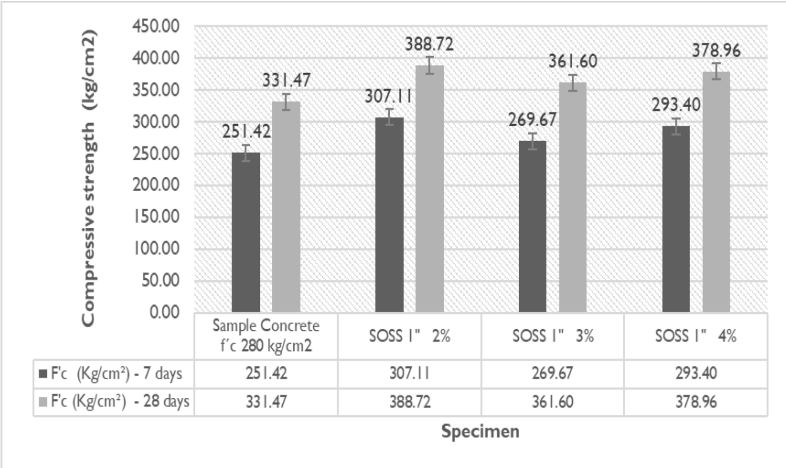


Source: Authors.

Properties of concrete in the hardened state

Compressive strength test: Figure 7 shows the results obtained for compressive strength, which reached the value of 251.42 kg/cm2 after 7 days of the curing stage and 331 kg/cm2 after 28 days as final resistance for the shows simple concrete pattern. Likewise, the optimal value of concrete with oxidized steel shavings was recorded with the addition of SOSS 1" at 2%, increasing its resistance 17.27% more with respect to the standard sample.

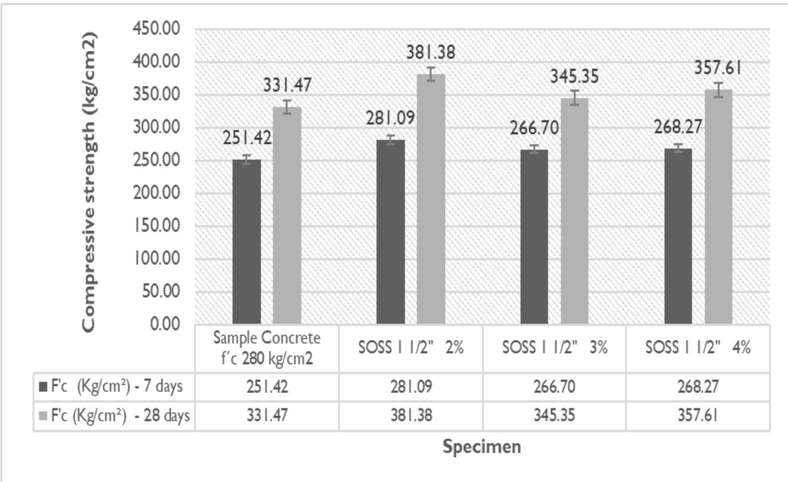
Figure 7. Compressive strength of SOSS 1".



Source: Authors.

Figure 8 shows the beneficial result for the addition of SOSS 1 ½" with a resistance of 281.09 kg/cm^2 at 7 days and 381.38 kg/cm^2 at 28 days.

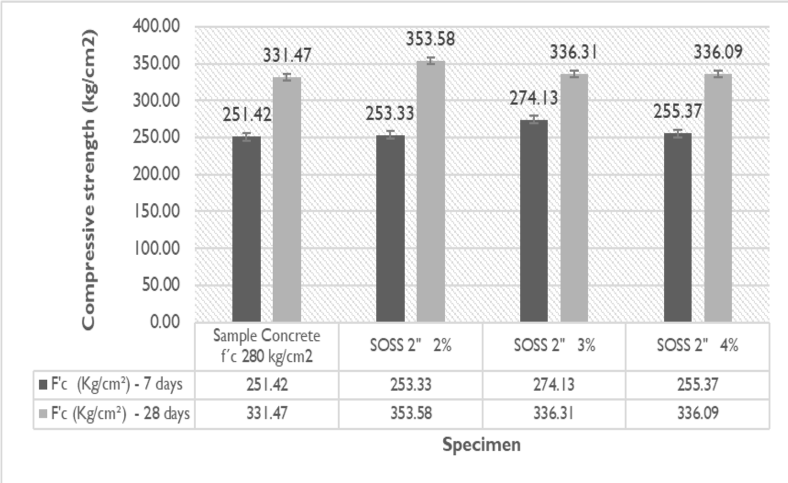
Figure 8. Compressive strength of SOSS 1 ½".



Source: Authors.

The results for SOSS 2" indicate that the resistance is not lower than the standard sample. However, SOSS 2" at 2% registered a 6.67% increase in compression compared to simple concrete.

Figure 9. Compressive strength of SOSS 2”

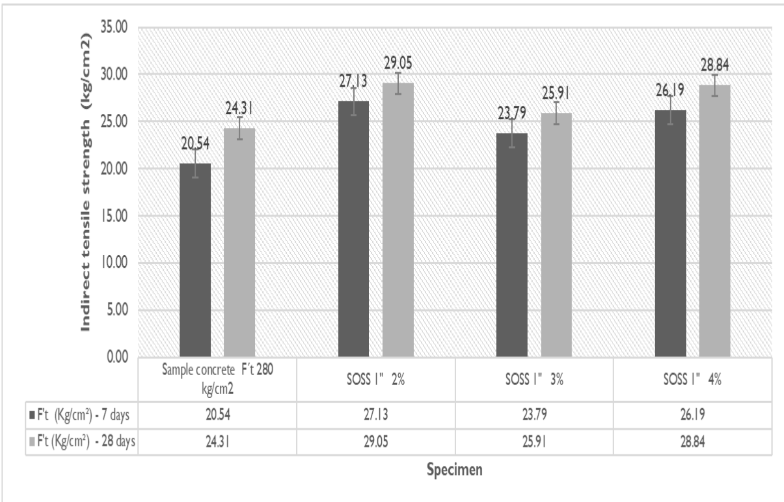


Source: Authors.

According to the records obtained in the compressive strength test, each of the added samples have not been inferior to the standard sample, all have presented an increase, whether minimal, such as the case of the SOSS 2" at 4% with 1.39%.

Indirect tensile strength test: The initial resistance of 20.34 kg/cm2 and final resistance of 24.31 kg/cm2 was determined for the standard sample. On the other hand, a minimum increase of 6.59% was obtained for SOSS 1" at 3% and a maximum of 19.51% in SOSS 1" at 2% at 28 days, as observed in figure 10.

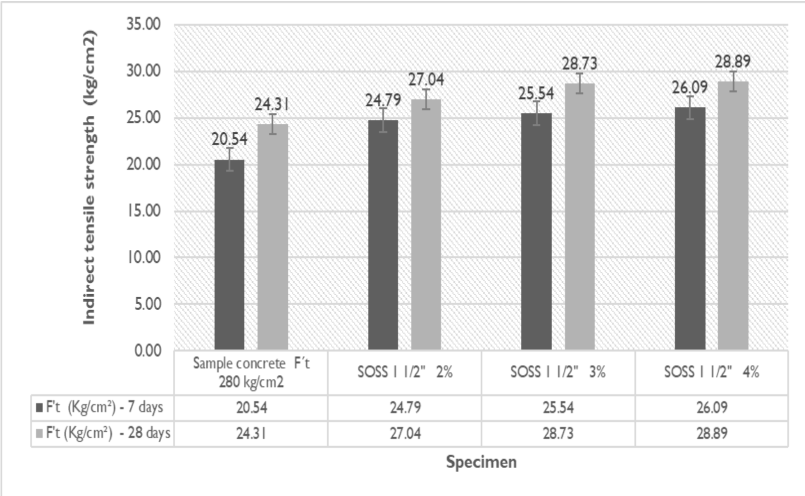
Figure 10. Indirect tensile strength of SOSS 1".



Source: Authors.

Figure 11 shows the performance of the 1 ½" SOSS at 7 days, which generated an increase in traction between 20% and 27%. However, the 1 ½" SOSS at 4% developed an increase of 18.86% at 28 days compared to the standard sample.

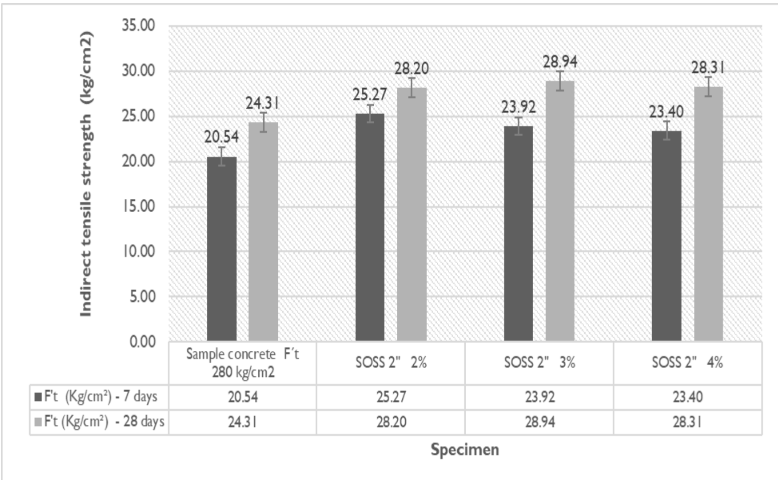
Figure 11. Indirect tensile strength of SOSS 1 1/2".



Source: Authors.

It can be seen in figure 12 that the resistance obtained to indirect traction at 7 and 28 days has been higher in all the percentages of addition of SOSS 2".

Figura 12. Indirect tensile strength of SOSS 2".



Source: Authors.

Flexural resistance test: Prismatic specimens were evaluated at 28 days, obtaining a resistance of 40.77 kg/cm2 for the standard sample and a value of 57.03 kg/cm2 for SOSS 1" at 4%, this would indicate that the most efficient performance has been achieved in short, oxidized steel shavings, with an increase of up to 39.36% as observed in table 4.

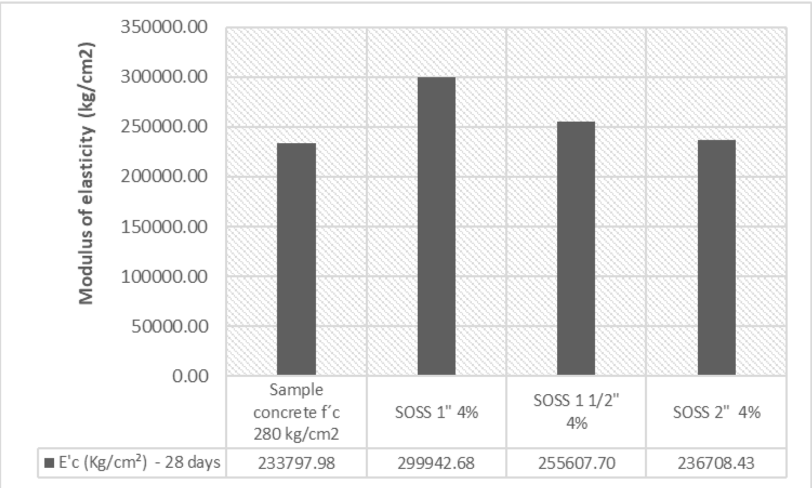
Table 3. Flexural resistance tests al 4%.

SAMPLE	Length and percentage of addition	Mr (Kg/cm²) - 28 days	Mr prom. (Kg/cm²) - 28 days	▲ %
Sample Concrete	M1 f´c 280 kg/cm2	40.92	40.843	100.00%
Concrete + Oxidized steel shavings	SOSS 1" 4%	57.0	57.026	139.36%
	SOSS 1" 4%	57.03		
	SOSS 1 1/2" 4%	52.78	53.523	130.80%
	SOSS 1 1/2" 4%	54.27		
	SOSS 2" 4%	55.22	55.638	135.97%
	SOSS 2" 4%	56.05		

Source: Authors.

Results of the modulus of elasticity test: An E'c of 233797.98 kg/cm^2 will be eliminated for simple concrete, in addition the additions of 4% SOSS remain above the E'c specified above, obtaining a significant increase of 299942 .68 kg/cm^2.

Figure 13. The modulus of elasticity of SOSS 4%.



Source: Authors.

Conclusions

- The settlement of the concrete was not affected by the addition of oxidized steel shavings, even with the increase of the percentage from 2% to 4%, it was confirmed that the treatment influences effectively.
- Through the concrete cracking potential test, it was concluded that the addition of oxidized steel shavings achieved a reduction of up to 69.7% in the appearance of cracks due to plastic contraction with respect to the standard sample.
- It was verified that the addition of SOSS 1” 4% considerably improves the flexural resistance by 39.36%, this is because the oxidized steel shavings were added with a smooth appearance, consequently generating an adequate adhesion together with the components of the concrete.
- Of the different types of additions considered in Table I, the SOSS 1” 2% developed a resistance at 7 days of 27.01 kg/cm2 and 29.05 kg/cm2 at 28 days, obtaining a behavior of superior indirect traction resistance compared to the simple concrete standard sample with 20.54 kg/cm2 and 24.31 kg/cm2 for 7 and 28 days respectively.
- In the same way, the addition of SOSS 1” 2% increased the final compressive strength from 331.46 kg/cm2 (standard sample) to 388.72 kg/cm2.
- In short, the results of the study show the efficiency of the oxidized steel shavings in the physical-mechanical behavior of the concrete, which in none of the tests carried out have obtained values lower than the standard sample, both in the plastic and hardened state. For this reason, the treatment that can be given to the different additions of the recycled type is of the utmost importance.
- To bring the use of oxidized steel shavings in simple concrete structures, such as urban pavements of local roads, to the engineering application field, the use is limited to areas: marine, with high humidity and average annual rainfall greater than 600mm.

Acknowledgements

We thank our parents, relatives who are not in the earthly world today, but from heaven they have guided us and provided the necessary vigor to carry out this investigation.

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