Incidence of Tara Ash on the Physical-Mechanical Properties of Concrete F'c = 350 Kg/Cm²

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The present research work entitled "Incidence of tare ash on the physical-mechanical properties of concrete f'c = 350 kg/cm2" proposed as general objective to determine the incidence of the incorporation of tare ash on the physical-mechanical properties of concrete f'c = 350 kg/cm2. The methodology belongs to the applied type with quasi-experimental design. The sample was census and consisted of 12 molds called Abrahams Cones; for the slump, 12 cylindrical molds; for the unit weight test, 72 cylindrical specimens; of which 36 were for the compression test and 36, for the diametral traction, of concrete f'c=350 kg/cm2 with replacement of tare ash in percentages of 0%, 6%, 12% and 16%, with respect to the cement. Tests were carried out to determine the physical and mechanical properties of the concrete in the 4 designs. The results indicated that the optimum amount of tare ash was 6%, presenting a slump of 3.47", a unit weight of 2.29 kg/cm3, compressive strength of 502.70 kg/cm2 and tensile strength of 37.18 kg/cm2. Thus, it was concluded that the incorporation of tara ash has a favorable effect on the physical-mechanical properties of concrete f'c= 350 kg/cm2.

Keywords: Concrete, tare ash, aggregates, compression, tensile.

1. Introduction

At the international level, according to Riquet (2018), it is increasingly necessary to specify a concrete with special characteristics and that comply with the properties established in the standards, to withstand the loads to which it will be subjected due to the complexity of the projects, such as large buildings, bridges, among others; that face unfavorable conditions of exposure of the structure (p.13).

On the other hand, according to Basquiroto (2019), in recent decades, in the production of concrete, great efforts have been made to reduce the gases emitted into the atmosphere with new alternatives for energy production. However, despite all the investments in renewable solutions, the share of coal in global energy production is still significant, as it is estimated that more CO2 is produced each year than is emitted when cement is produced (p.2).

At the national level, the disorderly development, the lack of adequate materials that make up concrete; mostly cement, aggregates and additives, and trained personnel to propose their use, pose one of the greatest risks in the event of a large earthquake, since it was discovered that many of the buildings have infrastructure problems because they do not comply with the building codes established in the technical standards, because they were built with poor quality concrete, that make them extremely vulnerable to this type of natural disaster. For this reason, specialists say that an earthquake of magnitude 8.8 (since the accumulated energy will only be released with an earthquake of this magnitude) could cause more than 110 thousand deaths, two million injured and the destruction of more than 353,000 homes. (Institute of Geophysics of Peru, 2023, p.1).

At the local level, the expansion of constructions in the city of Huancayo is increasingly evident because the place has been transformed, therefore, the population arouses interest in building houses with concrete of good properties, however, in this search they find poorly trained personnel who recommend deficient concretes made of materials of poor quality or dosing concrete in inadequate proportions that do not represent what is required by the structure. without first carrying out soil mechanics studies, analyzing the zoning, choosing the correct aggregates, using efficient cement, carrying out the appropriate mix design, carrying out tests on fresh concrete, among others, so that in the short or long term homes are affected by the consequences caused by concrete in poor condition, such as cracking and collapse of structural elements.

Regarding the international background, Charitha et. al. (2021), in their article called "Use of various agricultural residues in concrete for an effective reuse of locally available resources", carried out in India, set out to analyze the characteristics of various agro-industrial ashes for use in concrete. Using a scientific method with a non-experimental approach, where the potential of sugarcane ash, rice husk ash, palm oil ash, corn cob, coconut husk, cassava husk, wheat straw and bamboo leaves as alternative cementing materials in concrete is evaluated. In addition, the effects of these ashes on the workability, strength, water absorption, porosity, permeability, shrinkage by drying and resistance to acid and sulfate attacks of the mixed concretes are critically compared. The results revealed that concrete mixed with sugarcane and rice ash showed a better compressive strength (f'c) normalized among the ashes considered in the study; 254 kg/cm2 and 236 kg/cm2, respectively. Concluding that the inclusion of ash from agricultural residues decreases the segregation of concrete, with the exception of palm oil and wheat straw ashes. Permeability is reduced and, therefore, improves the durability of concrete mixed with agricultural waste.

In the same way, He, Kawasaki and Achal (2020), in their article called "Use of agricultural residues as agrocement in concrete", carried out in Japan, aimed to mainly examine current research on cement that has been replaced and applied to improve the durability of concrete, applying a non-experimental research design and descriptive level, by summarizing relevant knowledge and techniques, while providing optimal parameters for the application of agricultural residues in concrete. It turned out that the addition of 5% rice husk ash reached compressive strengths between 35 MPa and 55 MPa. Concluding that this natural additive is recognized as the most appropriate alternative material to volcanic ash, while other agricultural residues are also being studied on a large scale. In general, they have similar characteristics to ordinary Portland cement and can be used effectively in construction.

Likewise, Asfaw, Hareru and Ghebrab (2022), in their article entitled "Physical and chemical characterization of coffee husk ash and its effect on the partial substitution of cement in concrete production", carried out in Egypt, where they set the objective of establishing the characteristics of coffee husk ash through tests and conducting experiments to determine the mechanical strengths of the durability of the material, Its methodology was experimental through f'c, bending and tensile tests that were used to determine the strength of various concrete mixtures. The results have shown that, by increasing the amount of substitution, the crystalline material increases, the concentration of silicate decreases and the micropores or air vacuums also increase, which can cause a decrease in resistance, in addition, in the case of mechanical resistances, there has been a notable increase to 5% of substitution of said ash and it has also been strongly satisfied up to 10% of substitution, In addition, its increase to 20% is optimal for the production of normal concrete mix. Finally, it was concluded that the water absorption and sulfate attack of the partially replaced concrete are shown as an improvement in the durability of the concrete.

On the other hand, Khedheyer et. al. (2022), in Iraq, carried out an article called "Experimental investigation of the impact of the use of rice husk ash as a substitution material in concrete", where they set out to verify the impact of the addition of such ash in different proportions as a substitute for Portland cement. Its methodology was experimental and consisted of the prepared specimens being subjected to bending, compression, tensile, settling and rapid penetration tests of chloride ions to determine the suitability of their replacement by ordinary cementitious material by RHA in the concrete. The results showed that the maximum f'c was with 3% RHA at 30 days (37 N/mm2), flexural strength (6 N/mm2) and tensile strength (5 N/mm2). In addition, the reduction in particle size led to an increase in bulk density, which increases the strength of the concrete, so that the specimen with 3% addition was found to have the highest bulk density of 2.62 g/cm3, while the lowest bulk density was recorded at 7% ash with 2.40 g/cm3. In conclusion, the addition of fine (rather than more extensive) ash particles improves strengths and limits the penetration of chloride ions into the concrete.

Finally, in India, Vijay, Hari, and Vidya (2021), carried out an article entitled "Effect of wood ash as a partial substitute for cement on the effectiveness of concrete" and set out to determine the effect of wood ash as an alternative to cement on concrete performance, employing an experimental methodology by replacing the cementitious product with wood ash by 5%, 10%, 15% and 20%, and the performance of the concrete has been studied. The results indicated that the design that obtained the highest compressive strength was the 15% addition of ash with 46 MPa at the age of 28 days. Therefore, they concluded that the addition of wood ash as a partial alternative to cement improves the overall performance of the concrete.

Regarding the background at the national level, in Moquegua, Huaquisto, Cáceres and Quenta (2021), they prepared an article called "Resistance of concrete with inclusion of ash", whose objective was to verify the resistance of concrete with incorporation of vegetable ash, using an experimental design methodology, of applied type, where the specimens were prepared with variable amounts of fly ash and compared with the design concrete. As a result, after 28 days, all specimens reached the required resistances, with the design containing 2.5% fly ash reaching the highest resistance (220 kg/cm2). Also, it does not negatively alter the Slump. The conclusion was that less than 5% ash can be incorporated into the formulation of concrete mixes.

Similarly, in Chiclayo, Castillo, Chavarry, Peralta, and Muñoz (2021), in their article entitled "Use of agro-industrial residues in the mechanical properties of concrete: A literature review", aimed to identify the optimal percentages of agro-industrial ash to satisfy the mechanical characteristics of concrete, using a non-experimental, basic design method, where 62 indexed articles on the subject were reviewed. Where they reached the results that rice husk ash and sugarcane bagasse achieved optimal values of resistances, 445 and 35 and 34 kg/cm2, respectively. Concluding that the use of agro-industrial ashes has favorable effects since; in optimal percentages, increases mechanical properties

Likewise, Coronel, Altamirano, and Muñoz (2022), in their article entitled "Review of the literature on ash and fibers used in concrete production", carried out in Chiclayo, where their objective was to review the use of ash and fibers for concrete, using a descriptive methodology and looking for articles from 2015 to 2021 in Scopus, EBSCOhost, Scielo, ProQuest, and ScienceDirect, from which 55 studies were collected that used ash and fibers for concrete making. Where they reached the results that the design with 10% rice husk ash reached the highest resistance with a value of 577.16 kg/^{cm2}. Concluding that all the ashes had positive effects on the characteristics of the concrete.

On the other hand, Farfán and Pastor (2018), in their article entitled "Resistance of concrete with the addition of sugarcane bagasse ash", the authors set out to determine the effect of ash on f'c using the experimental method, partially replacing it with cement in a proportion of 20 and 40%. The results showed that the f'c decreased as the amount of ash increased below the mix design. Concrete containing 20% ash performed optimally at compression at the ages of 7 and 28 days, despite being 59% lower than (standard) control concrete. In addition, while the additive was being added, the Slump increased with the first addition by 8% and decreased with the second addition by 2%, with the value of the optimal percentage (20%) being 3.24 inches of settlement. It was concluded that this ash is not suitable for structural use.

On the other hand, in Huancavelica, Salas (2017), in his article called "Increasing the compressive strength of concrete by adding corn stubble ash", where the purpose was to examine the variation in the characteristics of concrete by incorporating ash, used the experimental method by adding ash to normal concrete. The results are that the tensile strength decreases very slightly from 20.99 kg/cm2 to 19.20 kg/cm2 and the f'c is 47.48% higher than that of the standard concrete evaluated at the same time. In conclusion, ash improves concrete strength and compaction, which is a fundamental aspect of their technology.

In relation to the above, this article was justified theoretically because it provided new knowledge on the use of tare ash, which is a pozzolanic additive studied to take advantage of its intrinsic characteristics in the optimization of the characteristics of concrete f'c = 350 kg/cm2, in addition to delving into previous studies of each of the variables. It was justified in a practical way because a solution to the problem of concrete quality was proposed by improving its characteristics with the addition of tare ash. Methodologically, it was justified because the research transcends by validating the subject with previous antecedents and theoretical bases, with which a new method was applied to elaborate a highly resistant concrete with the addition of tare ash for its subsequent use in buildings, foundations and bridges. Finally, it was socially justified because by giving a new use and employability to tara ash as a substitute for cement, pathologies in concrete are reduced and its mechanical resistance will be improved, giving way to the progress of civil engineering in the construction sector.

The general objective was to determine the incidence of the incorporation of tare ash on the physical-mechanical properties of concrete f'c = 350 kg/cm2. The specific objectives were the following: To establish the influence of the incorporation of tara ash on the settlement of concrete. To analyze the incidence of the incorporation of tare ash on the unit weight of concrete. To evaluate the effects of the addition of tare ash on compressive strength. To estimate the effects of the incorporation of tare ash on the diametrical tensile strength.

2. METHOD

The general method for the present work was scientific, because systematized procedures were used for the sequencing of the research to generate new knowledge about the relationship between tara ash and the properties of concrete.

The specific method used was the hypothetical-deductive, since deductive hypotheses were proposed based on general data on the significant increase in the physical-mechanical properties of concrete, to then verify their validity.

2.1 Type and design of research

The design was experimental of a quasi-experimental type, because it tested the predictive hypotheses by manipulating a single variable, which is the independent variable made up of the tare ash, to see the changes in the dependent variable that is the concrete. In addition, it was of an applied type, because new knowledge was applied and the requirement of concrete optimization was responded to with the incorporation of tare ash, which was verified with the tests of settlement, unit weight, compression and diametrical traction.

2.2 Variables and operationalization

Where the independent variable (VI) is the tare ash and the dependent variable (VD) is made up of the physical-mechanical properties of the concrete.

Operationally, variables are defined as follows:

VI: According to Vilcanqui (2018), tara is a fiber that contains a polysaccharide with a high molecular weight and is made up of 78.0% galactomannans, belonging to the soluble fiber type.

VD: According to Macedo (2019), the mechanical properties of concrete occur when a force is applied to a solid element, while mechanical properties are manifested by applying a force to a solid element.

Operationally, variables are defined as follows:

VI: Tara ash was incorporated by partially replacing it in percentages of 0%, 6%, 12% and 16% in the concrete mixture, depending on the weight of Portland Cement Type I (Cáceres and Quispe, 2018).

VD: Concrete f'c=350 kg/cm2 was tested to determine changes in its physical properties by means of settling (ASTM C 143), compacted unit weight (ASTM C138) tests and mechanical properties verified by compression (ASTM C39) and tensile (ASTM C496) tests.

Indicators

VI: Chemical Composition

VI: Specific Gravity

VI: Granulometry

VI: 0% Addition

VI: 6% Addition

VI: Addition of 12%

VI: Addition of 16%

VD: Concrete Settling Test

VD: Unit Weight Test of Concrete

DV: Compression test (age 7, 14 and 28 days)

VD: Diametrical tensile strength test (age 7, 14 and 28 days)

2.3 Population, sample and unit of analysis

It was made up of 12 molds called Abrahams Cones; for settlement, 12 cylindrical molds; for the unit weight test, 72 cylindrical specimens; of which 36 were for the compression test and 36, for diametric traction, of concrete f'c=350kg/cm2 with replacement of tare ash in percentages of 0%, 6%, 12% and 16%, with respect to cement.

In addition, the census sample was used because it included the entire population itself.

Likewise, for the settlement, it was composed of 3 concrete samples in the Abrahams cone of measurements: 10cm of minor base, 20 cm of major base and 30 cm of height, for each mixture design (pattern, 6%, 12% and 16% of tare ash addition).

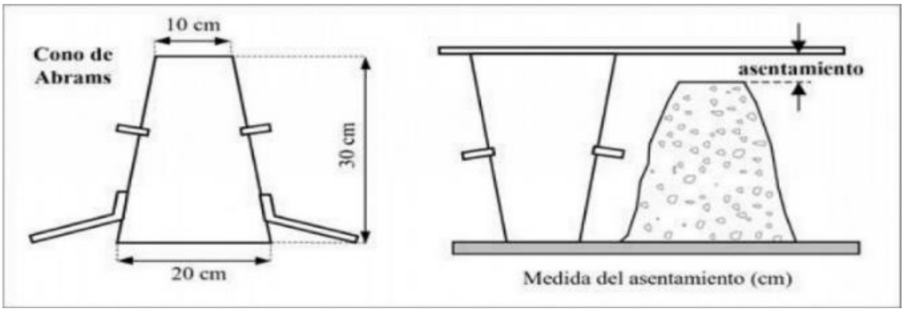

Figure 1. Dimensions of the cone of Abrahams.

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For flexural strength, the unit of analysis will be prismatic specimens measuring 0.60 cm x 0.15 cm and 7.5 cm in height. All

Likewise, for the unit weight test, the concrete was poured and compacted 3 times for each design in molds with dimensions of 18 cm in diameter and 25 cm in height.

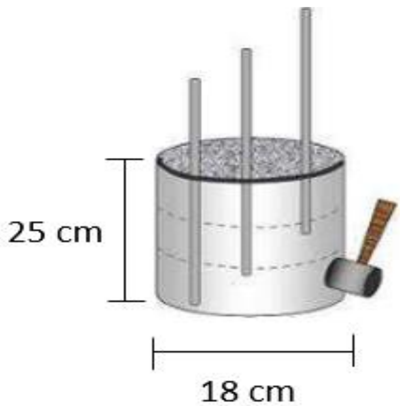

Figure 2. Mold dimensions for unit weight.

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Likewise, the analysis unit was made up of 36 cylindrical specimens of 10.16 cm in diameter and 20.32 cm in height; for compression evaluation and 36 equal specimens for bending test.

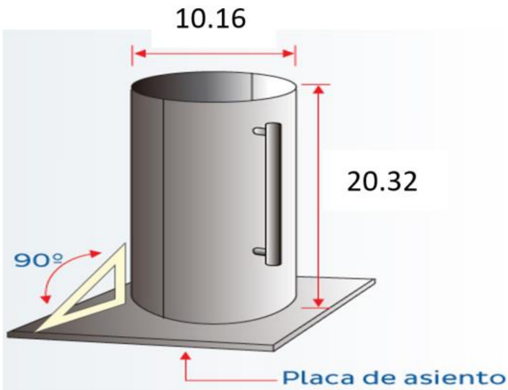

Figure 3. Specimen dimensions

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2.4 Data collection techniques and instruments

The technique of direct observation was used because it was possible to specify the behavior of the concrete before the addition of tare ash, in order to verify if the properties obtained complied with the parameters established by standard. Another technique to be used was documentary analysis, because information on the variables was extracted from different perspectives of the authors, which deepened the knowledge on the subject.

The instruments were made up of the following formats for aggregate granulometry (NTP 400.012), loose and compact unit weights of aggregates (ASTM C29), specific weights and absorption of fine aggregates (NTP 400.022) and coarse aggregate (NTP 400.021), settlement (ASTM C 143), unit weight of concrete (ASTM C138), compressive strength (ASTM C39), diametrical tensile strength (ASTM C496).

2.5. Procedure

The procedure consisted of:

First stage (cabinet); where the subject was investigated with bibliographic documentation, which consisted of master's and doctoral theses, scientific articles from indexed journals, Peruvian technical standards and international standards, manuals and books. The tare farms where the collection of this organic material was carried out were located. Then, the quarries from where the aggregates were purchased were located and the tests to be carried out were established, for which it was necessary to locate the laboratory certified by INACAL, where the tests were carried out. Accordingly, test formats were developed and calculations were made for the mixture design, to find the quantities; both in weight and volume and obtain the proportions of the materials.

Second stage (field); where the harvest of 50 kg of tara was made in a crop field that belongs to the Centro Poblado Compañía of the district of Pacaycasa, in the province of Huamanga, belonging to the Department of Ayacucho. The organic material was dried in the sun for 15 days and the dry material was transported in a sack to be tested. Subsequently, the coarse and fine aggregates were extracted from the Pilcomayo Quarry on Coronel Parra Avenue in the city of Huancayo, department of Junín. Then, the sieving and washing of the aggregates was done to make sure that they have a good quality and give good behavior to the concrete mixtures.

Third stage (laboratory); The dried tare was taken to be calcined at the chemistry laboratory of TECNOLABPERÚ S.A., where the material was subjected to muffle burning at a temperature of 800°C to 1000°C, for 1 to 2 hours. The particles were then ground and screened into the No. 200 mesh. In the image on the far left of Figure 10 the muffle can be seen, in the center the cooling of the ash at room temperature and on the right the sifted ash is observed as a final product. Tests were carried out on the fine and coarse aggregates. In the CENTAURO laboratory. First, for the granulometry test, the sample was quartered, mixing it, piling it up in the shape of a cone and dividing it into four parts with the help of a lamp until the sample was reduced to the necessary weight to be able to perform the test, which in this case was 200g for the fine aggregate and 1.5 kg for the coarse aggregate. Next, the aggregate was washed in mesh No. 200 to remove the very fine particles that can damage the concrete and it was put to dry in the oven at 110°C. Then the sieves for the fine aggregate were arranged, which included the meshes #3/8, 4, #8, #16, #30, #50, #100, #200 and bottom, to make the respective sieving for 5 minutes, recording the weights retained in each of the meshes separately. The same procedure was done for the granulometry of the coarse aggregates, using sieves from 1" to mesh N°200, including the bottom. Then the tests of specific gravity of the fine aggregate, specific weight and absorption of the coarse aggregate and unit weights of the aggregates were carried out.

Subsequently, the theoretical design of the mixture was made, calculating the dosages and then elaborating the mixture in the proportions given by means of the calculations for the design of mixtures made in the cabinet. It should be said that, if the mixture did not behave well as what was being sought, then the design was changed until the most suitable one was reached. Then the materials were mixed in the mixing machine taking the Slump and the unit weights to the mixtures of the 4 designs with 0%, 6%, 12% and 16% tare ash in replacement of cement. The mixture was poured into the 36 cylindrical specimens of 10.16 cm in diameter and 20.32 cm in height; for compression evaluation and 36 equal specimens, for tensile testing. The established ages (7, 14 and 28 days) were waited for, curing the specimens with clean water and at room temperature, to prepare them to break the specimens and verify if they met the expectations.

For the compressive strength test, he first placed the cylindrical specimen with the contact area facing the lower load plate, applying the load continuously with a speed of 0.5 Mpa/s, until reaching the maximum load that was evidenced with the first breakage of the specimen, recording the value and the form of failure. Consequently, the tensile strength test was carried out, for which the lying specimen was placed and the load was applied on the contact side (the longest side), to record the reading of the maximum load and the form of failure.

Fourth stage (Cabinet); Using the data and results obtained in the laboratory, the results were evaluated, to write the discussions where the main findings, the conclusions, which responded to the objectives set and the recommendations for future research were mentioned.

3. RESULTS

3.1 Calcination of tara ash

The results of the calcination of banana stem ash (PVC) were obtained, detailing the amount of ash and the dry base of the organic matter.

Table 1. Tara calcination results

Starting weight (gr)	Final weight (gr)	Calcination temperature (°C)
16150	15051.8	1000

From Table 8 it can be interpreted that the amount that was reduced when the tare was calcined was 1098.2 grams less, that is, it decreased by 6.8%, at a calcination temperature of 1000 °C.

3.2 Aggregate results

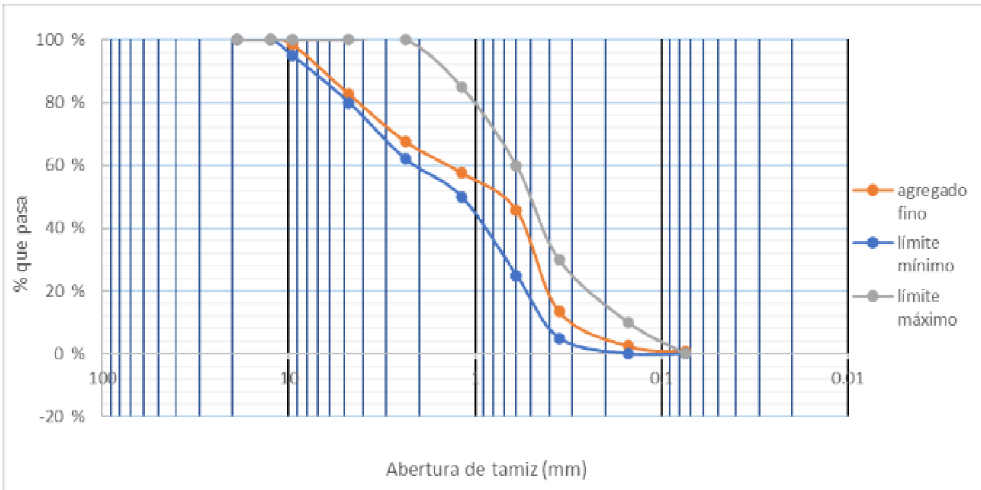

Figure 4. Granulometry of the fine aggregate.

According to the granulometric curve in Figure 4, it was possible to interpret that the granulometry of the fine aggregate complies with the minimum and maximum limits established by the NTP 400.037 standard, so it had a continuous distribution, therefore, they generated a good accommodation in the concrete.

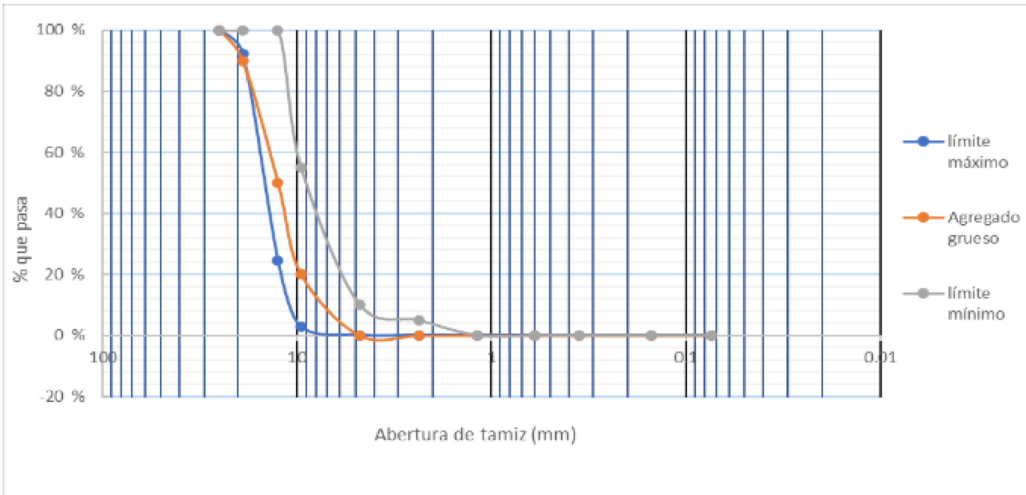

Figure 5. Granulometry of coarse aggregate.

According to the granulometric curve in Figure 5, it is interpreted that the granulometry of the coarse aggregate complies with the minimum and maximum limits established by the NTP 400.037 standard for Spindle No. 67 for a maximum nominal size of 3/4", so it had a continuous distribution of its particles and these were optimally accommodated in the concrete mixture.

Table 2. Aggregate Specific Density

Sample	Density	Specification	Norm
Fine Aggregate	3.09 gr/cm3	2.4 min	ASTM C33
Coarse aggregate	2.7 gr/cm3	2.4 min	

From Table 2, it can be interpreted that both the density of the coarse aggregate and that of the fine aggregate complied with the parameters specified by the ASTM C33 standard, as they were above the minimum limit of specific density (2.4 gr/cm3). This indicates that these aggregates will provide adequate strength when present in the concrete because they have an optimal density that is directly related to strength.

Table 3. Aggregate Absorption

Sample	Absorption	Specification	Norm
Fine Aggregate	1.56%	2% max	ASTM C33
Coarse aggregate	1.50%	3% max	

From Table 3, it is interpreted that the absorption of the coarse aggregate was 1.56% and complied with the standard by being below the allowed limit (2%). Likewise, the fine aggregate, having an absorption of 1.50%, was below the maximum allowed value (3%). Therefore, the ASTM C33 standard was complied with, which indicates that it will not absorb much water when making the concrete mixture, so its resistance will not be affected.

3.3 Mix Design

After making the calculations by the Fineness Modulus Method for the four designs, which can be seen in Annex 40, the proportions in weight and volume shown in Table 4 were calculated.

Table 4. Mix Design

Sample Design	Proportions by weight				
	Cement	Fine Aggregate	Coarse aggregate	Tara ash	Water (lt/bls)
Concrete pattern	1	1.54	1.69	0	16.97
Concrete with 6% tare ash	1	1.63	1.79	2.55	13.92
Concrete with 12% tare ash	1	1.74	1.92	5.1	13.92
Concrete with 16% tare ash	1	1.83	2.01	6.8	13.92

Table 4 shows that the proportions of tare ash increase according to the percentages of addition, so it can also be seen that the water increases because the proportions of fine and coarse aggregate also increase in a minimal way.

3.4 Concrete Settling

These results were obtained in order to achieve specific objective 1, which was to establish the influence of the incorporation of tare ash on the settlement of concrete.

Table 5. Settlement Results

Percentage of tare ash	Average Slump (mm)	Average Slump (in)
MC - 0%	154.23	6.07
MT - 6%	88.20	3.47
MT - 12%	82.89	3.26
MT - 16%	38.10	1.50

According to the results shown in Table 5, it could be seen that the control sample presented an average settlement of 154.23 mm so it is of fluid consistency, the treatment samples with 6% and 12% of addition of tare ash, presented settlements of 88.20mm, 82.89mm, respectively, presenting plastic consistency and the treatment sample with 16% had a value of 38.10 mm being the dry mixture. In addition, it can be interpreted that the level of workability of the samples with addition is moderate, with the exception of the last sample in the table that presents a low degree of workability.

3.5 Unit Weight of Concrete

The present results were obtained in order to carry out specific objective 2, which was to analyze the incidence of the incorporation of tare ash on the unit weight of concrete.

Table 6. Unit weight results

Percentage of tare ash	Unit weight (kg/m3)
MC - 0%	2330.36
MT - 6%	2296.26
MT - 12%	2283.53
MT - 16%	2269.34

According to the results shown in Table 6, it can be interpreted that the control sample presented a unit weight of 2330.36 kg/m3, which complies with the ASTM standard as it is greater than 2243 kg/m3, in addition, all the treatment samples comply with the provisions of the standard. In addition, it can be interpreted that the samples with 6%, 12% and 16% addition of tare ash decreased by 1.46%, 2.01% and 2.62%, respectively compared to the control sample, i.e. the concrete becomes less dense.

3.6 Compressive strength

The present results were obtained in order to be able to carry out specific objective 3, which was to evaluate the effects of the addition of tare ash on compressive strength.

- Compressive strength at 7 days

With the ruptures at 7 days, the results presented in Table 7 were obtained.

Table 7. 7-day f'c results

Percentage of addition of tara ash	Compressive strength at 7 days f'c (kg/cm²)
MC - 0%	333.57
MT - 6%	369.53
MT - 12%	389.87
MT - 16%	308.01

From Table 17, it can be seen that the standard sample did not reach the design compressive strength, which was 350 kg/cm² at the age of 7 days, representing 95.31% of the design concrete, however, with the additions of 6% and 12%, the strengths of these treatment samples had values of 369.53 kg/cm², 389.87 kg/cm², exceeding the design resistance by 5.58% and 11.39%, respectively, and exceeding the resistance of the control sample by 10.78% and 16.88%, respectively. It should be said that the sample with 16% natural ash had 12% less than the designer concrete and 7.66% less than the control sample.

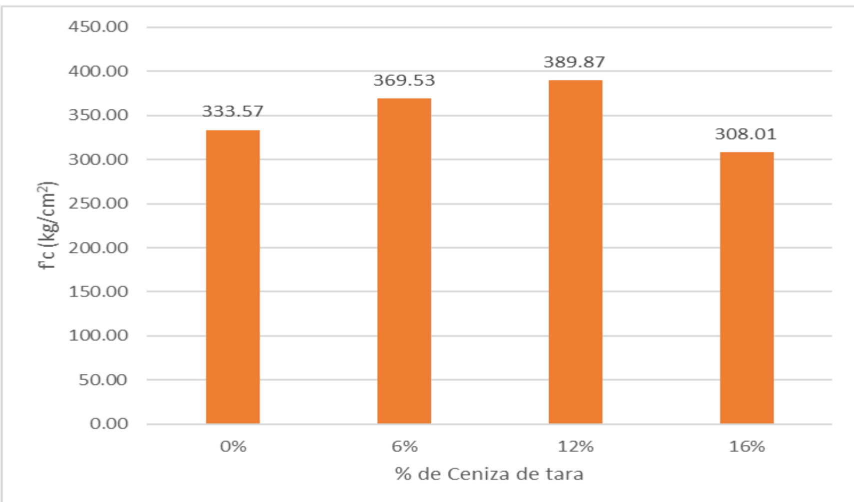

Figure 6. 7-day f'c chart

From the bar graph shown in Figure 6, it can be interpreted that as the percentage of tare ash increased, the f'c values of the treatment samples increased with 6% and 12%, so they had a direct relationship, where this property acts directly with the natural additive. Proving to be 12% addition, the optimal percentage as it would present the inflection point from which the compressive strength decreases. It should be said that, with the incorporation of 16% of tare, its value decreased by a percentage of 7.66%, compared to the control sample.

- Compressive strength at 14 days

With the ruptures at 7 days, the results presented in Table 8 were obtained.

Table 8. 14-day f'c results

Percentage of addition of tara ash	Compressive strength at 14 days f'c (kg/cm2)
MC - 0%	373.13
MT - 6%	410.67
MT - 12%	389.87
MT - 16%	343.40

Interpretation: From Table 8, it can be seen that, at an age of 14 days, all samples complied with the design value (350 kg/cm2) because they exceeded it with the additions of 0%, 9%, 12%, and 16% in percentage increases of 6.61%, 17.33%, and 11.39%, respectively. In addition, the treatment samples with 9%, 12% of addition increased their values by 10.06% and 4.48%, compared to the control sample and the last sample with 16% of the natural additive, decreased minimally by 0.6% unlike the concrete pattern.

- Compressive strength at 28 days

With the ruptures at 7 days, the results presented in Table 9 were obtained.

Table 9. 28-day f'c results

Percentage of addition of tara ash	Compressive strength at 28 days f'c (kg/cm2)
MC - 0%	429.07
MT - 6%	502.70
MT - 12%	429.67
MT - 16%	354.33

Interpretation: From Table 9, it can be seen that, at the age of 28 days, which is when the concrete acquired its greatest strength, all the samples exceeded the design value (350 kg/^{cm2}). In addition, the treatment samples with 9%, 12% of addition increased their values by 17.16% and 0.14%, compared to the control sample and the last sample with 16% of the natural additive, decreased its resistance by 17.42%, compared to the standard concrete.

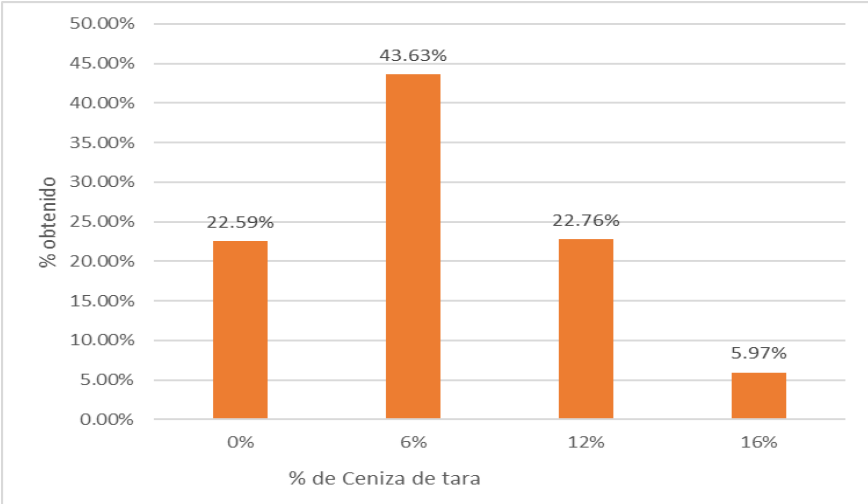

Figure 7. Graph of the percentage of f'c obtained

From Figure 7, which shows the graph of the percentage obtained with respect to the design strength, which is 350 kg/cm2, it is interpreted that, with the additions of 0%, 6%, 12% and 16%, percentage increases of 22.59%, 43.63%, 22.76% and 1.24%, respectively, are obtained, which were directly related to the natural additive. Proving to be 6% addition, the optimal percentage as it would present the maximum compressive strength.

- Comparison of f'c results at 7, 14 and 28 days

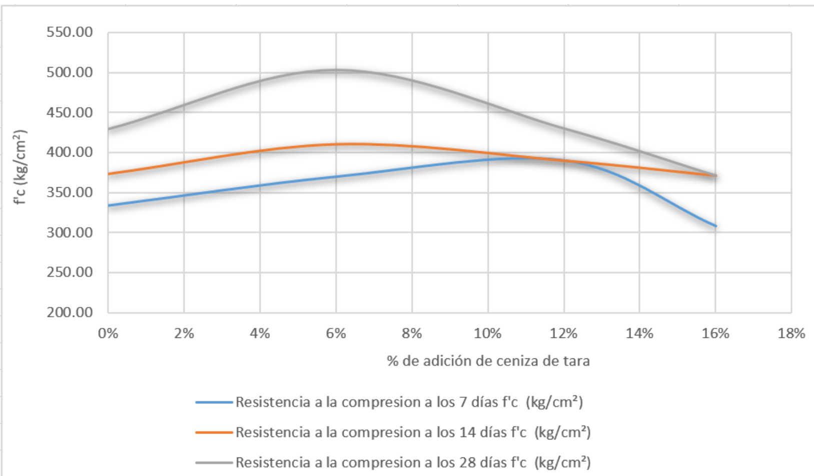

Figure 8. F'c chart at 7, 14 and 28 days

In Figure 8 you can see the comparison graph between the results of the compressive strength at the 3 different ages (7, 14 and 28 days), where it is possible to observe that at the age of 28 days the resistance reaches its maximum values, with a turning point of 502.70 kg/cm2 with 6% of natural ash addition. This turning point also coincides at the age of 14 days with a value of 410.67 kg/cm2 with the same addition. However, this behavior changes at the age of 7 days since the inflection point occurs with the addition of 12% showing a maximum resistance value of 389.87 kg/cm2. With what has been interpreted, it is verified that at 7 and 14 days the concrete does not demonstrate its true behavior, but it is at 28 days where its optimal percentage of addition can be notoriously verified, which in this case was 6% of tare ash.

3.7 Tensile strength

The present results were obtained to carry out specific objective 4, which was to estimate the effects of tare ash incorporation on diametrical tensile strength.

- Tensile strength at 7 days

With the ruptures at 7 days, the results presented in Table 10 were obtained.

Table 10. 7-day tensile strength results

Percentage of addition of tara ash	Tensile strength at 7 days (kg/cm²)
MC - 0%	29.26
MT - 6%	31.04
MT - 12%	28.74
MT - 16%	26.40

From Table 10, it can be seen that, at 7 days, with the additions of 6%, the tensile strength reached its maximum value of 31.04 kg/cm², surpassing the resistance of the control sample by 5.58%. It should be noted that samples with 12% and 16% natural ash had 1.79% and 9.78% less than the control sample.

- Tensile strength at 14 days

With the ruptures at 14 days, the results presented in Table 23 were obtained.

Table 11. Tensile strength results at 14 days

Percentage of addition of tara ash	Tensile strength at 14 days (kg/cm2)
MC - 0%	30.81
MT - 6%	29.45
MT - 12%	29.36
MT - 16%	26.95

Interpretation: From Table 21, it can be seen that, at the age of 14 days, the treatment sample with 6% increased its value by 2.37%, with respect to the control sample, and the treatment samples with 12% and 16% addition decreased their values by 4.71% and 12.53%, respectively, compared to the control sample.

- Tensile strength at 28 days

With the ruptures at 28 days, the results presented in Table 12 were obtained.

Table 12. Tensile strength results at 28 days

Percentage of addition of tara ash	Compressive strength at 28 days f'c (kg/cm2)
MC - 0%	36.53
MT - 6%	37.18
MT - 12%	36.24
MT - 16%	34.95

Interpretation: From Table 12, it can be seen that the treatment sample with 6% increased by 1.78%, and the treatment samples with 12% and 16% addition decreased their values by 0.79% and 4.33%, respectively, depending on the specific pattern. Therefore, the last 2 designs presented an inversely proportional behavior and the design with the first addition presented a direct behavior, with the addition of the natural material.

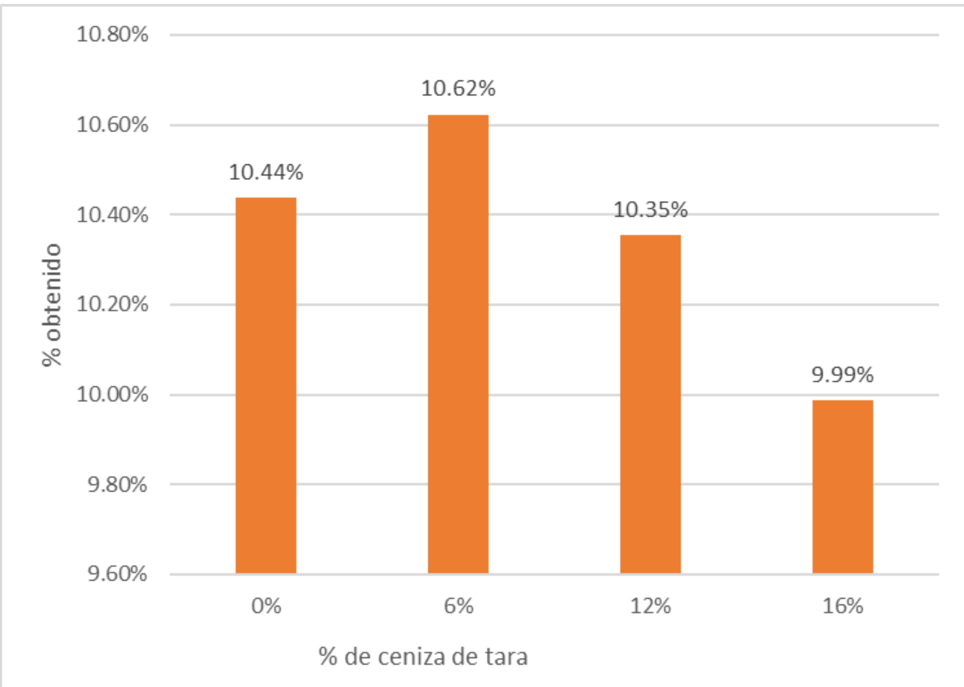

Figure 9. Graph of the percentage obtained of tensile strength at 28 days

From Figure 9, which shows the graph of the percentage obtained with respect to the design compressive strength, which is 350 kg/cm2, it is interpreted that the samples with addition with 0%, 6%, 12% and 16%, represented 10.44% and 10.62%, 10.35% and 9.99% of the design sample, respectively.

- Comparison of tensile strength results at 7, 14 and 28 days

Figure 10 shows the comparison graph between the results of the tensile strength at the 3 different ages (7, 14 and 28 days), where it can be observed that at the age of 28 days the resistance reaches its maximum values, with a turning point of 37.18 kg/cm2 with the 6% addition of natural ash. This turning point also coincides at the age of 14 days with a value of 31.54 kg/cm2 and, at 7 days with 31.04 kg/cm2 with the same addition.

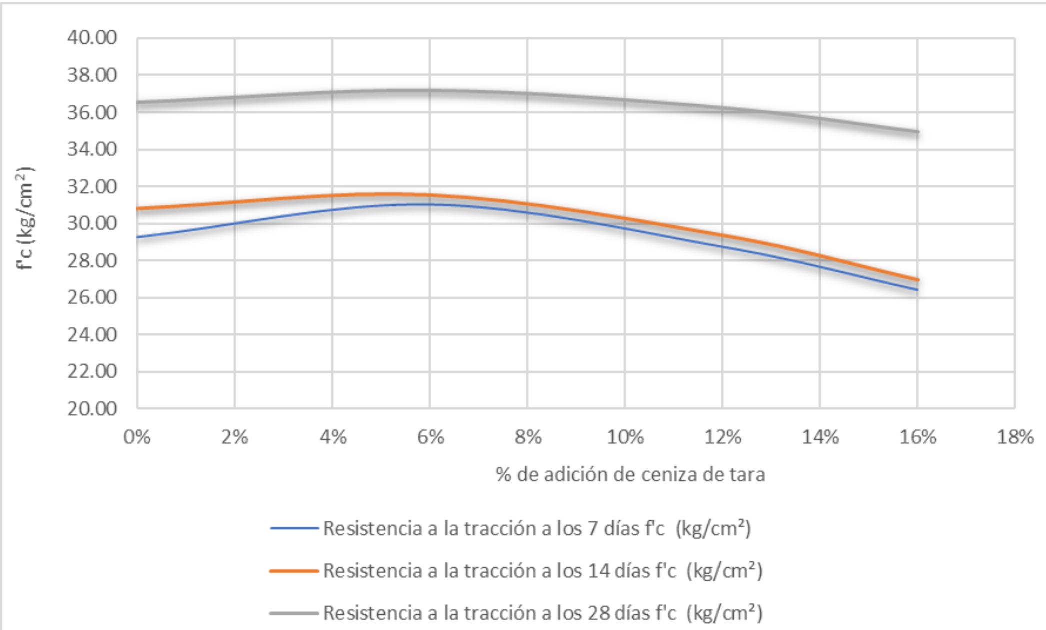

Figure 10. Tensile strength graph at 7, 14 and 28 days

4. DISCUSSION

The objective of this research was to determine the incidence of the incorporation of tare ash on the physical-mechanical properties of concrete f'c= 350 kg/cm2, for which a quasi-experimental design was used where laboratory tests were carried out with additions of 0%, 6%, 12% and 16% of tare ash depending on the weight of the cement to manufacture specimens. The results obtained from the 3 designs with additions were compared with those of the control sample and with the design concrete.

Regarding specific hypothesis 1, which deals with the settlement of concrete, the finding was that the treatment samples with 6%, 12% and 16% ash decreased their value by 42.81%, 46.26% and 75.30%, respectively, compared to the control sample, these decreases occurred gradually, as the percentage of tare ash increased, the settling values decreased, so they had an inverse relationship, where the Slump acted in a decreasing way with the natural additive. In addition, the control sample was of fluid consistency, the treatment samples with 6%, 12% of tare ash added, presented plastic consistency and the treatment sample with 16% had a dry mixture. Therefore, the level of workability of all samples was high, with the exception of the last sample, which has a moderate degree of workability.

According to the settlement of the concrete, as mentioned by Farfán and Pastor (2018), who added different percentages of sugarcane bagasse ash and found that while the additive was added, the Slump increased with the first addition by 8% and decreased with the second addition by 2%, with the value of the optimal percentage (20%) being 3.24 inches of settlement. It is agreed, because they have similar behavior, since with the additions the settlement values were also reduced, keeping a very close value, of 3.47" with the optimal percentage. However, this optimal addition (6% tare ash) was lower than in the author's study.

On the other hand, in the research of Huaquisto, Cáceres, and Quenta (2021), who with the incorporation of plant ash, the Slump was not negatively altered. Where the conclusion was that an amount less than 5% of ash can be incorporated into the formulation of concrete mixtures. This is very close to the percentage used in the present study since it was found that no more than 6% of tara ash could be added because its properties decreased. He also agrees that the settlement was altered in a positive way because the concrete became more consistent in plastic form, which allowed its workability.

According to the hypothesis test, it was found that the data were distributed in a normal way and with the ANOVA test the significances were less than 0.05, so the null hypothesis (Ho) was rejected and the alternate hypothesis (Ha) was accepted, therefore, it was possible to verify that there is sufficient evidence to affirm the assertion that the incorporation of tara ash favorably influences the settlement of concrete.

Regarding specific hypothesis 2, which dealt with the unit weight of the concrete, it was found that the samples with 6%, 12% and 16% of tare ash addition decreased by 1.46%, 2.01% and 2.62%, respectively compared to the control sample, that is, the concrete became less dense. Because, while the percentage of natural additive was increased, the unit weight was decreasing, that is, they kept an inverse relationship, so the unit weight acted decreasing with the incorporations.

According to the results of the unit weight of the concrete, as indicated by Khedheyer et. al. (2022), who obtained as results that the reduction of the size of cement particles by replacement with rice husk ash, led to an increase in unit weight, so that the specimen with 3% addition turned out to have the maximum of 2.62 g/cm3, while the minimum was recorded with 7% of ash with 2.40 g/cm3. In conclusion, the addition of fine (rather than more extensive) ash particles improved densities. This is dissimilar with the present study because with tare ash the unit weight was inversely related, in addition the optimal addition percentage was 3% higher compared to the previous study.

Regarding the hypothesis testing, through the statistical analysis it was determined that they had a normal distribution and with the ANOVA test the significances were less than 0.05, for which Ho was rejected and the Ha was accepted, and thus the assertion that the incorporation of tare ash favorably affects the unit weight of the concrete could be affirmed.

According to specific hypothesis 3, regarding compressive strength at 28 days, it was found that the treatment samples with 9%, 12% of addition increased their values by 17.16% and 0.14%, compared to the control sample and the last sample with 16% of the natural additive, decreased its resistance by 17.42%. with respect to the specific pattern. In addition, with respect to the design strength, which is 350 kg/cm2, it is interpreted that, with the additions of 0%, 6%, 12% and 16%, percentage increases of 22.59%, 43.63%, 22.76% and 1.24%, respectively, were obtained, so that the compressive strength was directly related to the natural additive. On the other hand, from the results of the 3 different ages (7, 14 and 28 days), it was possible to observe that at the age of 28 days the resistance reaches its maximum values, with a turning point of 502.70 kg/cm2 with 6% of natural ash addition, this inflection point also coincides at the age of 14 days with a value of 410.67 kg/cm2 with the same addition. However, this behavior changes at the age of 7 days since the inflection point occurs with the addition of 12% showing a maximum resistance value of 389.87 kg/cm2.

For Charitha et. al. (2021), who when adding sugarcane ash and rice, a better normalized compressive strength (F'c) of 254 kg/cm2 and 236 kg/cm2, respectively, was shown, so both ashes from agricultural residues improved the durability of the concrete. This coincides with the results of the present study because the ash used improved the compressive strength of the concrete by exceeding all the samples to the design resistance, achieving a maximum strength of 502.70 kg/cm2, which was far from the results of previous work, showing a better behavior and more favorable results with the tare ash. differing significantly.

In addition, in the research of He, Kawasaki and Achal (2020), who added 5% rice husk ash, they reached a maximum compressive strength of 560,844 kg/cm2. Concluding that this natural additive is recognized as the most appropriate alternative material because it has properties similar to those of cement. This affirms the present research because the ash used presented an incremental behavior of resistance due to its components that were mostly the same as cement, but in different quantities. In addition, the maximum resistance, which was 502.70 kg/cm2, was very close to the resistance achieved by the authors, verifying the agreement between both results.

In addition, researchers Vijay, Hari and Vidya (2021), that when adding wood ash as an alternative to cement, the design that presented the maximum compressive strength was 15% addition with 469.07 kg/cm^2, at the age of 28 days, for which they concluded that the addition of wood ash improves the overall performance of the concrete. These results agree on the behavior of ash to improve concrete. However, they are dissimilar, since the present optimal percentage of tare addition (6%) was of lower quantity, obtaining a higher maximum resistance, which determines that, with the natural material present, better compressive strengths are obtained with less quantity.

Finally, according to the hypothesis testing, according to the statistical analysis, it was verified that the data were normal and applying the ANOVA parametric test, a p value of less than 0.05 was obtained, with which the Ho was rejected and Ha was accepted, that is, there were sufficient data to ensure the assertion that the addition of tare ash significantly increases the compressive strength.

According to specific hypothesis 4, regarding tensile strength, it was found that the treatment sample with 6% increased by 1.78%, and the treatment samples with 12% and 16% addition decreased their values by 0.79% and 4.33%, respectively, compared to the control sample. Therefore, the last 2 designs presented an inversely proportional behavior and the design with the first addition presented a direct behavior, with the addition of the natural material. In addition, regarding the design strength, which is 350 kg/cm2, it was found that the samples with addition with 0% and 6%, 12% and 16%, represented 10.44%, 10.62%, 10.35% and 9.99% of the design sample, respectively. On the other hand, from the results of the tensile strength at the 3 different ages (7, 14 and 28 days), where it is possible to observe that at the age of 28 days the resistance reaches its maximum values, with a turning point of 37.18 kg/cm2 with 6% of natural ash addition, this point also coincides at the age of 14 days with a value of 31.54 kg/cm2 and, at 7 days with 31.04 kg/cm2 with the same addition.

For Khedheyer et. al. (2022), who by using rice husk ash in an optimal percentage of 3%, as a substitution material in concrete, found that the maximum tensile strength was 50.98 kg/cm2, for which they concluded that the addition of fine (instead of more extensive) ash particles improves the tensile strength. These results coincide in the behavior of ash to improve concrete. However, they are dissimilar, since the present optimal percentage, being 6%, was of greater quantity, obtaining a lower maximum resistance, 37.18 kg/cm2, with which it is determined that, with the natural material present, lower tensile strengths are obtained than those of the previous author.

In addition, in the study by Salas (2017), who added corn stubble ash, the results were that the tensile strength decreased very slightly from 20.99 kg/cm2 to 19.20 kg/cm2, which constitutes a 9% decrease. This does not agree, since the results of the tensile strength increased in the first instance, but then began to decrease while more ash was incorporated, however, the optimal percentage obtained an increase of 1.78% with 6% ash, the results being better than those of the previous study, thus differentiating itself from it.

According to the hypothesis testing, according to the statistical analysis, it was verified that the data were normal and applying the ANOVA parametric test, a p value of less than 0.05 was obtained, with which the Ho was rejected and Ha was accepted, that is, there were sufficient data to ensure the assertion that the addition of tare ash significantly increases the compressive strength.

5. CONCLUSIONS

Regarding the general objective, it was determined that the incorporation of tare ash favorably affects the physical-mechanical properties of the concrete f'c = 350 kg/cm2, because the optimal addition was 6% with values of 3.47" of settlement, unit weight of 2296.26 kg/m3, 502.70 kg/m2 and kg/m2, in the compressive and tensile strength. respectively, showing an increase of 43.63% and %, compared to the concrete pattern. In addition, with the inferential statistical analysis it was found that all the data had a normal distribution, and with the ANOVA test, the significances were less than 0.05, so the alternative hypothesis was accepted and the null hypothesis was rejected.

In reference to specific objective 1, it was established that the incorporation of tare ash favorably influences the settlement of concrete, since the treatment samples with 6%, 12% and 16% of ash decreased their value by 42.81%, 46.26% and 75.30%, respectively, compared to the control sample, becoming a mixture of plastic consistency and more workable.

Regarding specific objective 2, it was concluded that the incorporation of tare ash favorably affects the unit weight of the concrete, since the samples with 6%, 12% and 16% of tare ash addition decreased by 1.46%, 2.01% and 2.62%, respectively compared to the control sample, that is, the concrete became less dense.

In reference to specific objective 3, it was concluded that the addition of tare ash significantly increases compressive strength, because the treatment samples with 9%, 12% of addition increased their values by 17.16% and 0.14%, compared to the control sample. In addition, with respect to the design strength, which is 350 kg/cm2, it is interpreted that, with the additions of 0%, 6%, 12% and 16%, percentage increases of 22.59%, 43.63%, 22.76% and 1.24%, respectively, were obtained.

In reference to specific objective 4, it was concluded that tare ash significantly increases the diametrical tensile strength, because the treatment sample with 6% addition increased its value by 1.78%, compared to the control sample and exceeded the design strength by 10.62%.

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