

The Use of Fourth Glaciation Moraine Aggregate in Freeze-Thaw Manufactured Concrete

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Abstract The useful life of concrete in areas prone to freezing and thawing has been a challenge for its preservation, since these environments cause cracks and deterioration in the material. Therefore, the purpose of this research was to determine a concrete durable to freezing and thawing under the standards of ASTM 666, which is made of a material of the fourth glaciation - the morainic aggregate, for which air incorporating additive was used. Preliminarily, for compressive strength, values of 33.72 MPa were obtained in the samples without incorporating air subjected to freezing and thawing; however, in the samples when incorporating air subjected to freezing and thawing, it was reduced to 31.18 MPa. Next, for the tensile strength, values of 3.88 MPa were obtained in the samples without incorporating air subjected to freezing and thawing; however, in the samples when incorporating air subjected to freezing and thawing, it was reduced to 3.31 MPa. Finally, it is concluded that the use of morainic aggregate in concrete improves compressive and tensile strength. Despite the moderate loss of strength due to freeze-thaw cycles, the concrete still retains superior mechanical strength compared to its design strength.

Keywords Moraine Aggregate, Fourth Glaciation, Freezing, Thawing

1. Introduction

Currently in areas with seasonal ice and thawing changes, it has been observed that concrete structures experience significant damage, resulting in a reduction in their service life and leading to considerable economic losses. This damage can manifest itself in the form of cracking, spalling and even structural collapse, compromising the integrity and safety of buildings. The need to understand and mitigate these adverse effects has been recognized as a crucial challenge in the construction industry [1]. Peru has 71% of the world's tropical glaciers, distributed in 20 mountain ranges that host 3,044 glaciers in total, covering an area of 1,958 km²; all located in the Andes [2]. Moraines are formed here, including the San Antonio and Huaytapallana glaciers, located east of Huancayo, approximately 150 km south of Jun ín. These glaciers have left moraines on the valley floor at an altitude of 3400 m [3]. Moraines are accumulations of sediments created by glacial activity. These deposits can be found in different places and of different types, such as at the end of the glacier tongue on the valley sides or on the valley floor. Finland is located the hummocky moraine field of kemijarvi, the moraine of this site is considered polygenic and the geomorphometric study showed that the presence of stones on the surface is characteristic of moraine mounds, and this aggregate comes from the last glacial period which

is called Weischselian, an extension of frozen bedding with rib instability. These cores are composed of fill gravels and coarsely stratified diamictic sequences. The abundant presence of boulders and cobbles at the top of the mounds is identified as an indicator of coarse-textured sediments. This characteristic is crucial for the mapping of these reservoirs of materials that have potential to be used in construction after crushing and mechanical screening processes. This approach makes it possible to identify and take advantage of valuable resources for infrastructure development and construction projects [4]. In another investigation, expanded graphite (EG) was used to encapsulate n-tetradecane (C14), thus creating a phase change composite material (PCM) expanded graphite encapsulated n-tetradecane (EGC14). A series of tests indicated that EGC14 is chemically stable and has excellent phase change capability, and freeze-thaw cycling (FTC) resistance tests showed that EGC14 prevents capillary and transition pores from expanding into macropores that are easily damaged by FTC. In addition, phase change concrete (PCC) with 3% EGC14 showed the optimum durability under freezing and thawing conditions, meeting the strength requirements of concrete. In conclusion, PCC with 3% EGC14 is the most durable under freezing and thawing conditions, being recommended for real engineering applications [1]. A comparison of the construction costs of hot mix asphalt (HMA) construction using aggregates from different regions and geological formations was carried out in Poland. The results showed that aggregates from glacial deposits are effective for asphalt pavement structural layers. It was concluded that Poland has a relatively abundant reserve of high quality aggregates from the Cenozoic glaciations, specifically from the Tertiary and Quaternary. These crushed aggregates from glacial formations have the potential to produce mixtures that meet the standards required for high traffic roads [5]. The coefficient of thermal expansion (CTE) in a typical concrete pavement mix was measured using six different types of coarse aggregates: glacial gravel, quartzite, granite, diabase, basalt and dolomite. The estimated concrete tensile strength values, calculated according to the American Association of State Highway and Transportation (AASHTO) Empirical-Mechanistic Pavement Design Guide for Level 2 Concrete Pavement Design, were considerably lower (17-31%) than the actual experimentally determined values. The analysis showed a marked variation in the CTE of concrete when using different types of aggregates. Concrete with quartzite aggregate presented the highest CTE, followed by dolomite, glacial gravel, granite and finally diabase and basalt. This variability in CTE values

highlights the significant influence of aggregates on the thermal properties of concrete [6]. Since there is little research on the use of glacial aggregates in the manufacture of concrete exposed to freezing and thawing, this study seeks to fill the knowledge gap on the properties of concrete made with this type of aggregate in regions such as the department of Junín, which experiences periods of frigid weather. The objective is to evaluate the impact of freezing and thawing on the mechanical properties of medium-strength concrete made with moraine aggregate from the fourth glaciation in central Peru. Moraine aggregate from glacial deposits, clean and well graded sand according to ASTM C33 [7], and gravel according to ASTM C33 [7] were used. In addition, an air incorporator was used according to ASTM C260 [8]. For the preparation of the mixtures, the indications of ACI 211.1 [9] were followed, dividing the process into two series: one with the air-entraining admixture and the other without it. It was ensured that the mixture was homogeneous, following the guidelines of ASTM C192 [10]. Subsequently, the molds were filled in compliance with ASTM C31 [11]. The cylindrical specimens were subjected to compression tests according to ASTM C39 [12]. In addition, indirect tensile testing was performed on the same specimens, following ASTM C496 [13]. A group of specimens was exposed to freeze-thaw cycles according to ASTM C666 [14]. The results showed that specimens with morainic aggregate without air entraining additive had an increase in compressive and tensile strength, also an increase in compressive and tensile strength after being subjected to freezing and thawing. The specimens with morainic aggregate with air-entraining additive showed an increase in compressive and tensile strength, and after being subjected to freezing and thawing there is an increase in compressive strength and a reduction in tensile strength.

2. Materials and Methods

In this research article, the moraine aggregate and fine aggregate were extracted from the Chaclas quarry. For the study of the materials and their tests, standard E 060 [15] was used; likewise, special tests were carried out on concrete subjected to freezing and thawing, which were used in relation to standard ASTM 666 [14]. On the other hand, the compressive and indirect tensile strength was analyzed according to NTP 339.034 [16].

Next, in order to have a better understanding of the characteristics of the samples, nomenclatures were used as shown in Table 1.

Table 1. Menclature of the samples

TEST	BASE DESIGN (M)	AIR (A)	FREEZING AND THAWING (FT)	DESCRIPTION	NOMENCLATURE
COMPRESSION (1)	X			Samples without incorporating air	(M1)
	X		X	Samples subjected to freezing and thawing without incorporating air	(M1+FT)
	X	X		Samples with air incorporation	(M1+A)
	X	X	X	Air-entrained samples subjected to freezing and thawing	(M1+A +FT)
TRACTION (2)	X			Samples without incorporating air	(M2)
	X		X	Samples subjected to freezing and thawing without incorporating air	(M2+FT)
	X	X		Samples with air incorporation	(M2+A)
	X	X	X	Air-entrained samples subjected to freezing and thawing	(M2+A+FT)

2.1. Moraine Aggregate

They are debris of glacial origin that are located in the distal part of the glacial tongue, on the edges of the valley or in the interior of glacial valleys. Their elevation varies between 2 and 7 meters (average 3 meters) above the summit of the plateau, and their width fluctuates between 20 and 150 meters [17]. They are also located on the edge of the valley or within glacial valleys.

On the other hand, a series of tests were established to determine the characteristics or properties of the moraine aggregate as shown in Table 2 below.

Table 2. Granulometric Analysis of Soil

# (in)	Mesh (mm)	Retained Weight (g)	% Detained	% Passes
1 ½	37.5	-	-	100
1	25	-	-	100
¾	19	1,024.0	20.5	79.5
½	12.5	2,216.0	44.3	35.3
3/8	9.5	844.0	16.9	18.4
N ¼	4.75	878.0	17.5	0.9
N ⅛	2.36	25.5	0.5	0.4
N °16	1.18	2.5	0.0	0.3
N °30	0.6	1.7	0.0	0.3
N °50	0.3	1.3	0.0	0.3
N °100	0.15	2.2	0.0	0.2
N °200	0.075	4.1	0.1	0.1

According to the granulometry Table 2, the moraine aggregate presents gradations of 81.6% retained up to the 3/8" (9.5mm) sieve. The moisture content was determined using a drying oven with a temperature capacity of 110 ± 5 °C and Table 3 was used to determine the amount of wet sample for the test.

Table 3. Recommended mass

Maximum particle size (passes 100%)	Standard mesh size	Minimum recommended mass a ± 1%
2mm.or less	2.00 mm (N ° 10)	20 g
4.75 mm	4.75 mm (N ° 4)	20 g
9.5 mm	9.51 mm (3/8")	50 g
19.0 mm	19.0 mm (3/4)	250 g
37.5 mm	38.1 mm (1/2")	1 kg
75.0 mm	76.1 mm (3")	5kg

A 5 kg moraine aggregate sample was used for this test, as shown in Figure 1.

**Figure 1.** Moraine aggregate

Next, the percentage of fractured particles test was performed, where the mass of the test sample should be

large enough so that the largest particle does not constitute more than 1% of the total mass [18], as shown in Figure 2.



Figure 2. Fractured Particles (Sharp Edges, Rough Surfaces)

In addition, the dry test sample was spread out on a long, flat, clean surface to allow close inspection of each particle. To verify whether a particle meets the fracture criterion, the face of the aggregate particle was observed directly. If the face spans at least one quarter of the maximum cross section of the rock particle, it is classified as one or more fractured faces [19], as shown in Table 4 below:

Table 4. Percentage of one or more fractured faces

Aggregate size		A(g)	B(g)	E
Pass sieve	Retained sieve			
1 1/2"	1"	0.0	0.0	0.00%
1"	3/4"	1515.0	1515.0	68.12%
3/4"	1/2"	501.9	493.1	22.17%
1/2"	3/8"	207.0	207.0	9.31%
Total		2.224		99.6%

Applied to the moraine aggregate, a 99.6% fractured face of the moraine aggregate was obtained. Subsequently, the Los Angeles Abrasion test was carried out where the machine was used, which consists of a hollow steel cylinder, closed at both ends, with an internal diameter of 711 mm ± 5 mm (28 in. ± 0.2 in.) and an inner length of 508 mm ± 5 mm (20 in ± 0.2 in) and the charge shall consist of approximately 46.8 mm (1 27/32 in) steel spheres. The Los Angeles machine was loaded and rotated at a speed between 30 and 33 rpm for 500 revolutions, as shown in Figure 3.

After completing the prescribed revolutions, the material was discharged from the machine and a preliminary separation of the sample was performed using a standardized 1.70 mm sieve (No. 12) [19], resulting in a wear of 21.26% and soluble sulfates parts of 84 parts per million (ppm), which indicates that the material has a low sulfate content, which is positive to avoid deterioration problems in concrete [20]. The following Table 5 shows the

tests carried out.



Figure 3. Los Angeles Abrasion Test

Table 5. Recommended mass

Test	Rule	Result
Los Angeles Abrasion	MTC E 207	21.26%
Soluble sulfates	NTP 339.178	84 ppm

2.2. Fine Aggregate

Similar tests were used for the moraine aggregate where the same procedure was used for moisture content NTP 339.185 [21], organic impurities and soluble sulfates MTC E207 [19], in addition to this, the equivalent sand test was performed using a cylindrical can of approximately 57 mm (2 1/4") diameter, with a capacity of 85 mL ± 5 mL [22]. Finally, the quantitative analysis of magnesium sulfate test was carried out using a saturated solution of chemically pure magnesium sulfate by dissolving the salt in water at a temperature of 25 °C to 30 °C [19]. The results of these fine aggregate tests are shown in Table 6 below.

Table 6. Maximum amount of materials

Test	Rule	Result
Moisture content	NTP 339.185	6.20 %
Sand equivalent	NTP 339.146	71.00 %
Magnesium sulfate quantitative analysis	MTC E 209	3.16 %
Soluble sulfates	NTP 339.178	88 ppm

2.3. Cement

Portland cement is an easily accessible product on the market, sold in bags that have a net weight of 42.5 kg and one cubic foot of capacity that, when mixed with water, either alone or together with sand, stone or other similar materials, reacts slowly with water until it becomes a hardened mass. Essentially, it is a clinker, finally pulverized, and produced by firing at high temperatures mixtures containing lime, alumina, iron and silica in

specific proportions. Table 7 shows the main components that represent 90% of the cement [23].

Table 7. Main components of cement

Name	Abbreviation
Tricalcium silicate (3CaO.SiO ₂)	C3S
Dicalcium silicate (2CaO.SiO ₂)	C2S
Tricalcium aluminate (3CaO.Al ₂ O ₃)	C3A
Aluminum tricalcium ferrite (4CaO.Al ₂ O ₃ .Fe ₂ O ₃)	C4AF

2.4. Additive

SikaAer is a liquid admixture designed to incorporate air into concrete. This admixture can be used in doses of 0.02% to 0.12% of the weight of the cement; in addition, it does not contain chlorides, so it does not cause corrosion in metals; it is recommended that the admixture be kept at room temperature between 20 °C to 25 °C. For the mode of use of the air-entraining admixture, the following Table 8 is recommended.

Table 8. How to use the air-entraining additive

How to use	Additive amount (mL)	Concrete quantity (Kg)
SikaAer	51	42.5

2.5. Freezing and Thawing

Subjecting wet concrete to freeze-thaw cycles presents a significant challenge to the material, especially when it is nearly fully saturated. When the structural element is wet and water freezes, its volume expands, generating internal stresses in the concrete that can lead to its failure [24]. For normal weight concrete to resist freezing, its water-cement ratio should not exceed the values given in Table 9.

Table 9. Water-cement ratio requirements for concrete exposed to freeze-thaw cycles

Exposure conditions	Maximum ratio a/c	Minimum compression strength (MPa)
Concrete exposed to freeze-thaw cycles in a wet condition	0.45	31

This test method covers the determination of the resistance of concrete samples to rapid and repeated cycles of freezing and thawing in the laboratory, using two different procedures: Procedure A, rapid freezing and thawing in water, and Procedure B, rapid freezing in air and thawing in water. Specimens will be maintained between -2 °F and +4 °F (-1 °C and +2 °C) of thawing temperature, respectively. The transition period between the freezing and thawing phases of the cycle should be less than 10 minutes, likewise each specimen in the test should be subjected until 300 cycles are reached [25].

2.6. Preparation of Specimens

Once all the material properties were obtained, the mix design was carried out using the fineness modulus. This methodology consists of several stages that are mentioned below. First, a sequence of logical and direct steps must be taken into account, these are: Maximum water/cement ratio, minimum cement content, air content, slump, maximum aggregate size, with which the fineness modulus was calculated using the following formula as shown in Equation 1.

$$MF = \frac{\sum \% \text{retained_accumulated from } 6'' \text{ to } N^{\circ}100}{100} \quad (1)$$

Subsequently, the proportions of each material used for the sample and with the addition of concrete admixture F'c = 310 kg/cm² were obtained through the mix design, as shown in Table 10 and Table 11. 144 cylindrical concrete specimens of 4“(101.6 mm) in diameter and 8”(203.2 mm) in height were prepared, as shown in Figure 4.

Table 10. Proportions for concrete F'c=310 kg/cm² of control sample

Material	Design	Weight per batch
Cement	496.55 kg/m ³	42.50 kg/bl
Effective water	167.91 lt	15.08 Lt/bl
Fine aggregate	911.52 kg/m ³	78.02 Kg/bl
Coarse aggregate	671.24 Kg/m ³	57.45 kg/bl

Table 11. Proportions for concrete F'c=310 kg/cm² of sample with SikaAer additive

Material	Design	Weight per batch
Cement	496.55 kg/m ³	42.50 kg/bl
Effective water	163.01 lt/m ³	14.66 Lt/bl
Fine aggregate	911.52 kg/m ³	78.02 Kg/bl
Coarse aggregate	671.24 Kg/m ³	57.45 kg/bl
SikaAer	4.9 l/m ³	0.42 Lt/bl



Figure 4. Cylindrical samples

2.7. Compressive Strength

The method consists of applying an axial compressive load to the molded cylinders at a speed (MPa/s) that is in a prescribed range until failure. To determine the compressive strength of the specimen, it is calculated by dividing the maximum load achieved during the test by the cross-sectional area of the specimen. All test cylinders for a given age will be fractured within the allowable time tolerances, specified in Table 12, either in hours (h) or days (d).

Table 12. Test ages and allowable tolerances

Trial age	Allowable tolerance
24h	±0,5 h or 2,1 %
3d	± 2 h or 2,8 %
7d	± 6 h or 3,6 %
28d	± 20 h or 3,0 %
90d	± 48 h or 2,2%

If the breaking base block is new it shall be at least 25 mm thick, and at least 22.5 mm thick after any surface treatment operation. The maximum diameter of the support block of the suspended spherical base shall not exceed the values given in Table 13:

Table 13. Maximum diameters of test specimens

Diameter of test specimen, (mm)	Maximum diameter (mm)
50	105
75	130
100	165
150	255
200	280



Figure 5. Compressive Strength Test

The load will be applied at a speed of movement

measured from the platen to the crosshead corresponding to a stress speed on the specimen of 0.25 ± 0.05 MPa/s [16] as shown in Figure 5.

2.8. Linear Regression Equation

Linear regression was used to predict the compressive strength (C), using this statistical technique to find the relationship between several independent variables that are factors and a resultant that is the independent variable. Equation (2) is the basic equation of linear regression.

$$Y = mx + b \quad (2)$$

y: dependent variable.

x: independent variable.

m: slope of the line.

b: intersection with the “y” axis.

Independent variables: Tensile strength (TS), Air incorporation (AI), subjection to freezing and thawing (FT), finally, the number of days (D) of curing.

Dependent Variable: Compressive strength (C).

Dummy variables or dichotomous variables: These are variables that take values of 0 or 1, including Air incorporation (AI), ice subjection and thawing (FT).

3. Results

3.1. Compressive Strength in Samples without Incorporating Air (M1)

Figure 6 shows the development of the compressive strength of cylindrical concrete specimens in samples without incorporating air (M1), where at 28th day of age they reached an average strength of 35.14 MPa, which with the increase to 56th day reached 41.38 MPa and at 72nd day presented a strength of 44.13 MPa.

3.2. Compressive Strength of Samples Subjected to Freezing and Thawing without Incorporation of Air (M1+FT)

Figure 7 shows the results of the compressive strength test of cylindrical concrete specimens in samples without incorporating air subjected to freezing and thawing (M1+FT), where an average strength of 36.15 MPa was reached at 28th day of age, complying with the design strength, from that age it was subjected to freezing and thawing in cycles of 24 hours of freezing and 24 hours of thawing up to 72 days of ages. The results obtained at 56th day showed a resistance of 38.76 MPa and at 72nd day the resistance was reduced to 33.72 MPa, however, this result is above the design resistance of 30.41 MPa. Development of compressive strength without entrained air is subjected to freezing and thawing

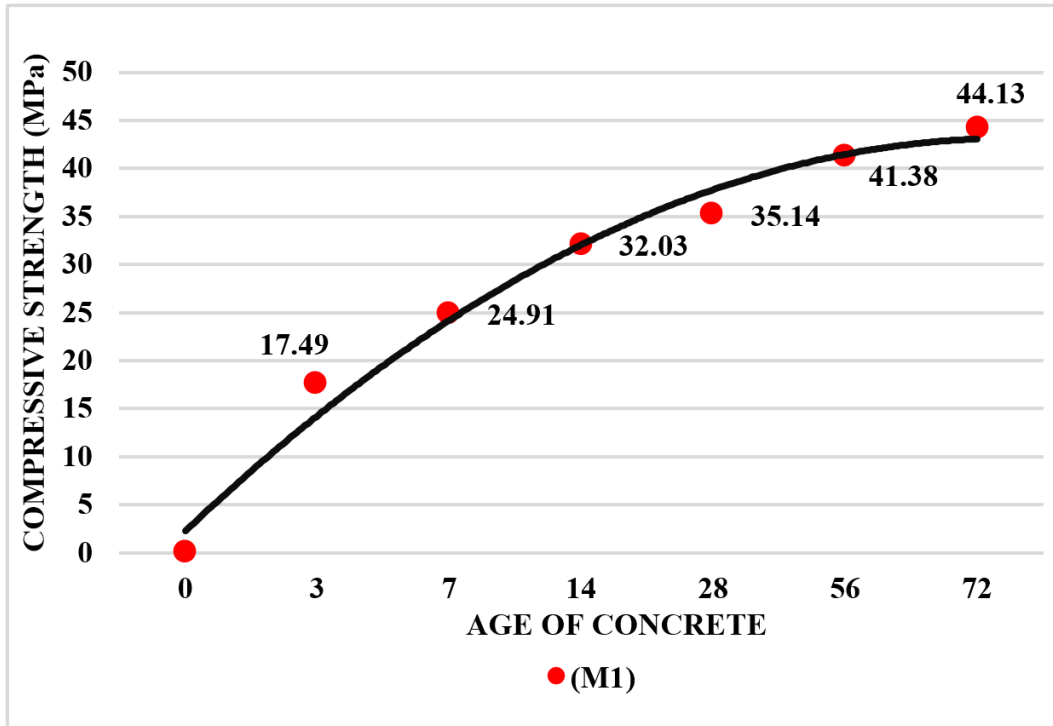


Figure 6. Development of compressive strength without incorporation of air

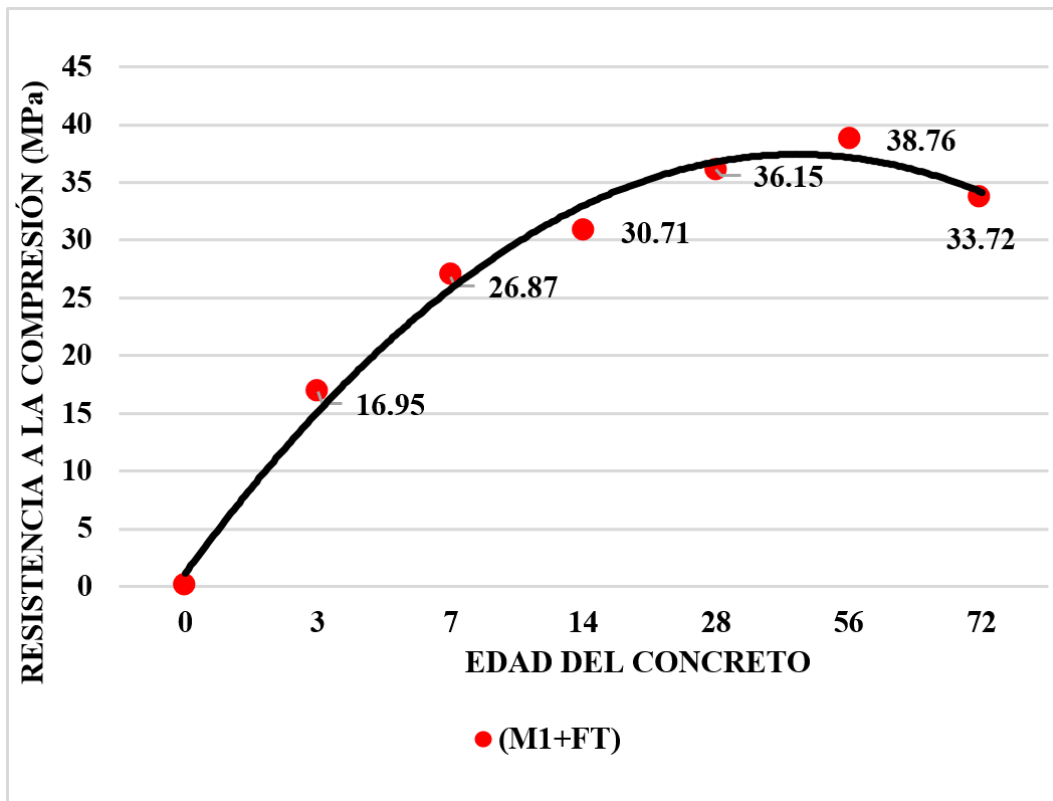


Figure 7. Compressive strength development without incorporated air subjected to freezing and thawing

3.3. Compressive Strength in Samples with Air Entrainment (M1+A)

Figure 8 shows the experimentation with cylindrical specimens incorporating air in the sample (M1+A), which evaluated the compressive strength at 28th day reaching 32.56 MPa thus exceeding the design strength, the samples at 56th day increased to 36.56 MPa and at 72nd day reached a strength of 38.11 MPa.

3.4. Compressive Strength of Air-Entrained Samples Subjected to Freezing and Thawing (M1+A+FT)

Figure 9 shows the results of the samples of cylindrical specimens incorporating air and subjected to freezing and thawing (M1+A+FT). It was observed that at 28th day it presented a resistance of 33.73 MPa and with the increase to 56th day it reached 37.84 MPa; however, at 72nd day this decreases to 31.18 MPa, but remains above the design resistance of 30.41 MPa.

3.5. Compressive Strength Comparison

Figure 10 shows the compressive strength results of (M1), (M1+A), (M1+FT), (M1+A+FT), (M1+A+FT) at 3, 7, 14, 28, 56 and 72 days, where the sample (M1) increased its compressive strength up to 45.12% at 72nd day with respect to the design strength of 30.41 MPa, likewise the same sample (M1) increased up to 36.07% at 56th day with respect to the design strength of 30.41 MPa, thus surpassing

the other samples at 56th day and 72nd day.

3.6. Tensile Strength in Samples without Incorporating Air (M2)

Figure 11 shows the results of the tensile strength test of cylindrical specimens without incorporating air (M2), which showed that at 28th day of age it presented an average tensile strength of 3.77 MPa, with the increase to 56 days it reached 4.44 MPa and at 72nd day it presented a tensile strength of 4.86 MPa.

3.7. Tensile Strength in Samples without Incorporating Air Subjected to Freezing and Thawing (M2+FT)

Figure 12 shows the results of the tensile strength of the samples (M2+FT), where it presented a value of 3.74 kPa at 28th day, from that age it was subjected to freezing and thawing in cycles of 24 hours of freezing and 24 hours of thawing until 72nd day of age, whose results were obtained at 56th day a strength of 3.99 MPa and at 72nd day the strength was reduced to 3.88 MPa.

3.8. Tensile Strength with Air Entrainment (M2+A)

Figure 13 shows the experimentation with cylindrical specimens incorporating air into the sample (M2+A), which evaluated the tensile strength at 28th day reaching 3.21 MPa, the samples at 56th day increased to 3.68 MPa. And after 72 days it reached a resistance of 4.05 MPa.

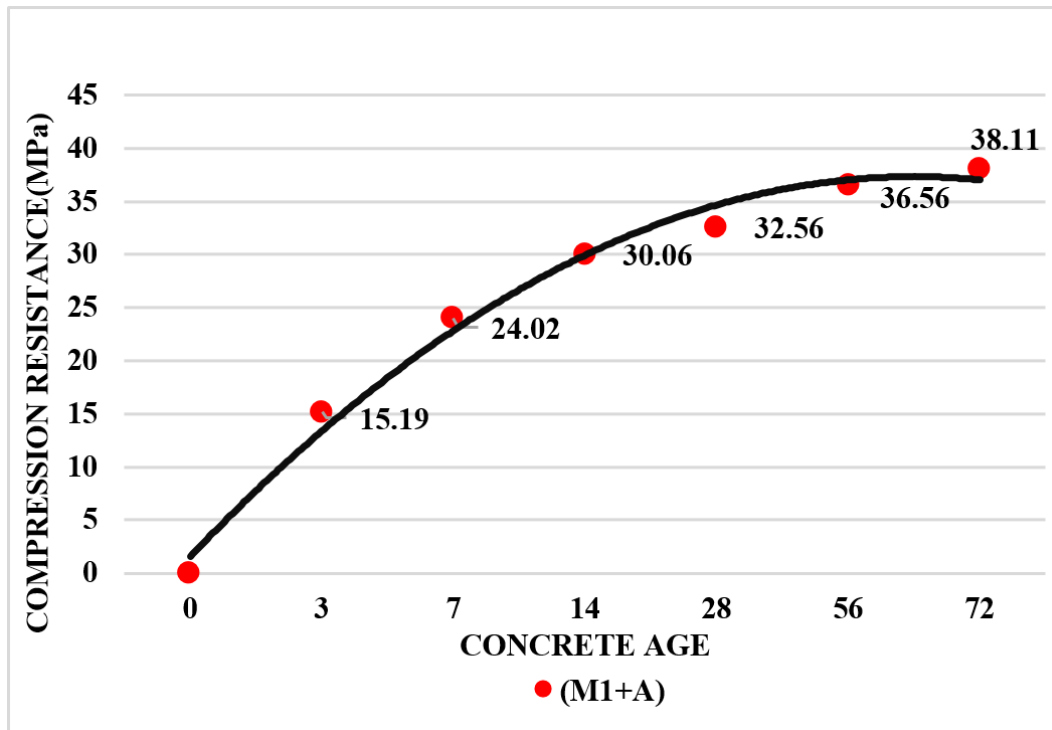


Figure 8. Development of compressive strength with entrained air

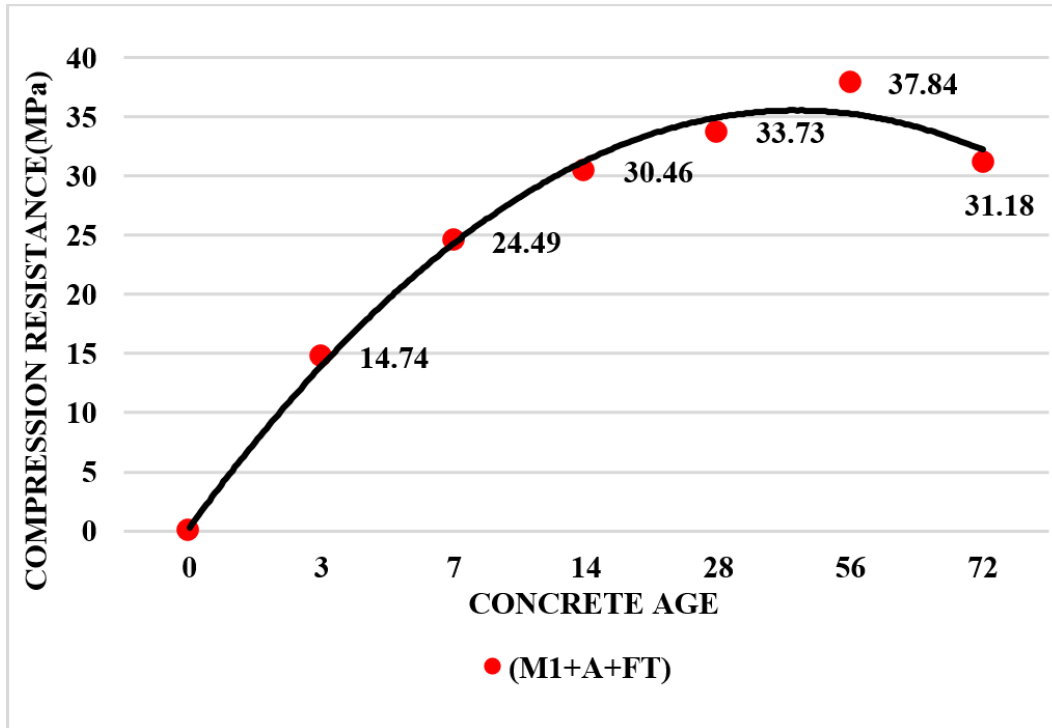


Figure 9. Development of compressive strength with entrained air, subjected to freezing and thawing.

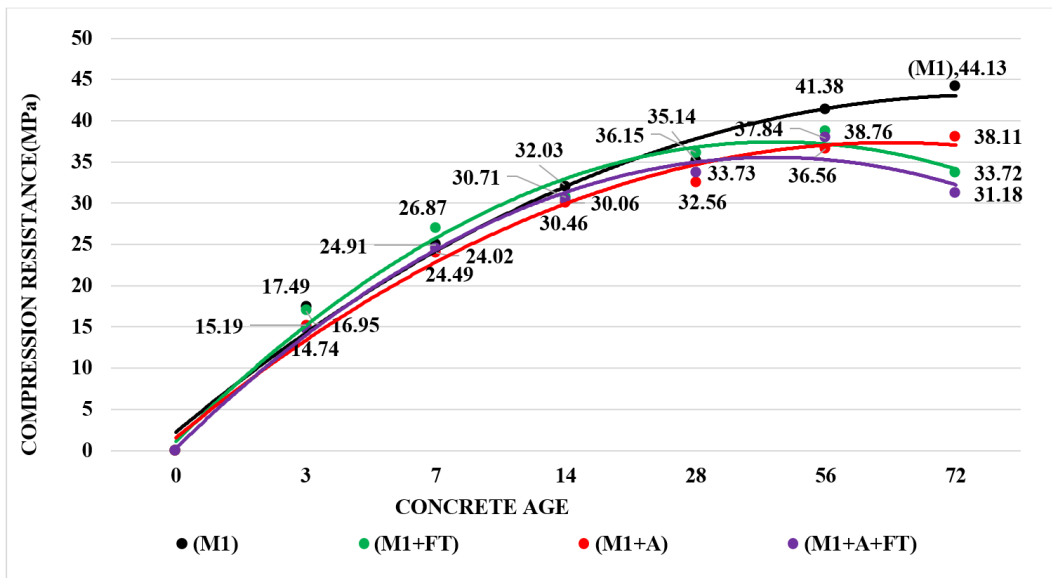


Figure 10. Summary of comparison of compression samples

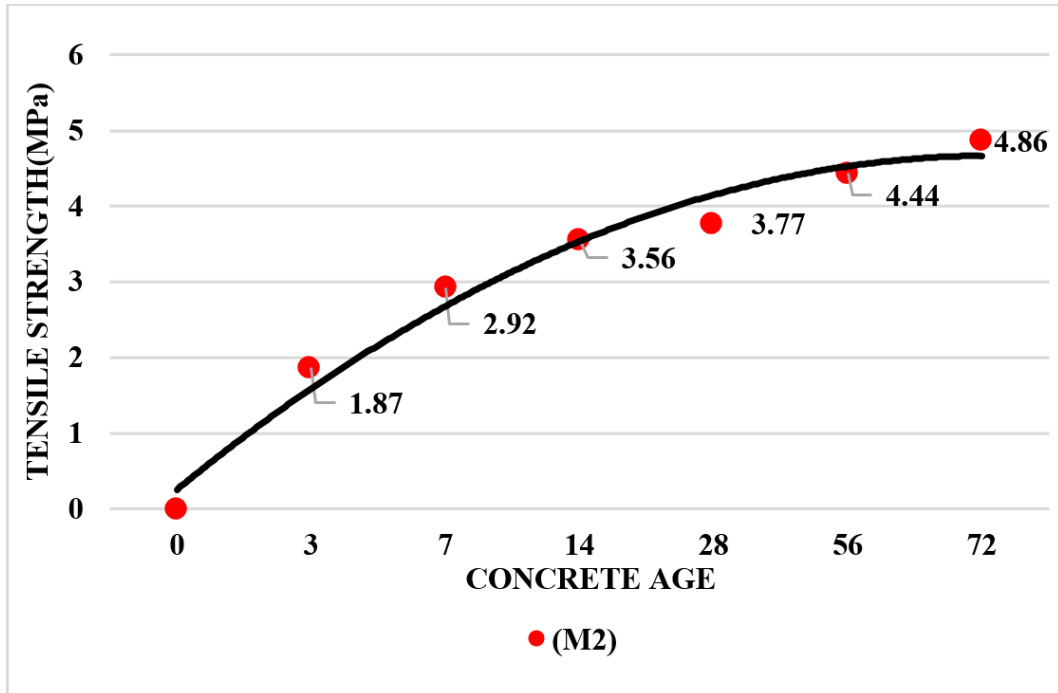


Figure 11. Development of tensile strength without entrained air

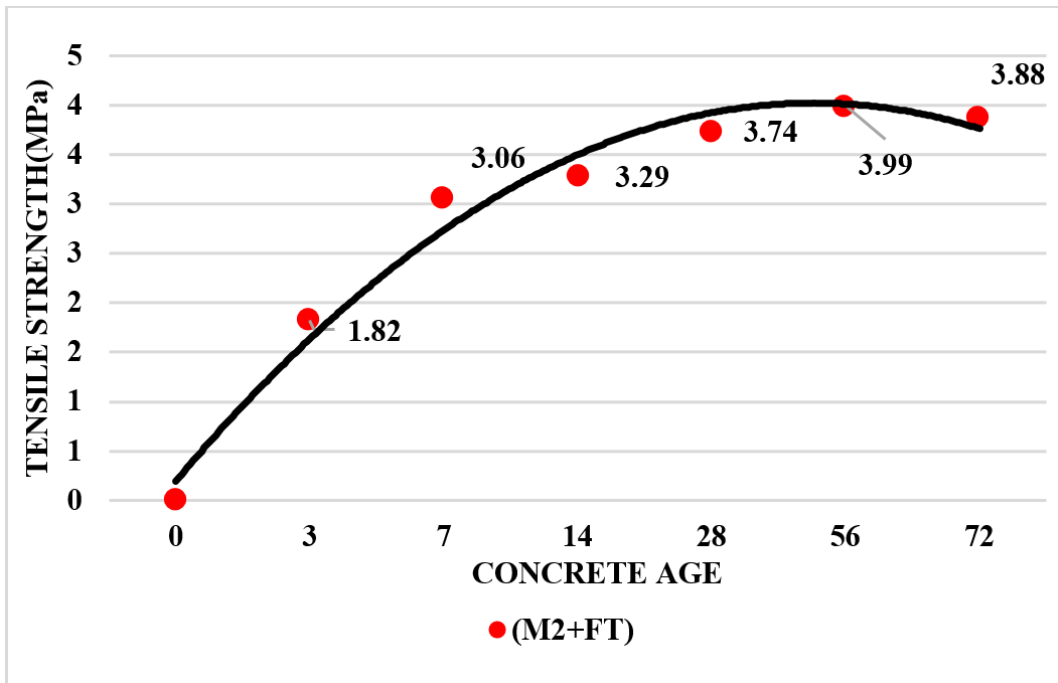


Figure 12. Development of tensile strength without entrained air subjected to freezing and thawing

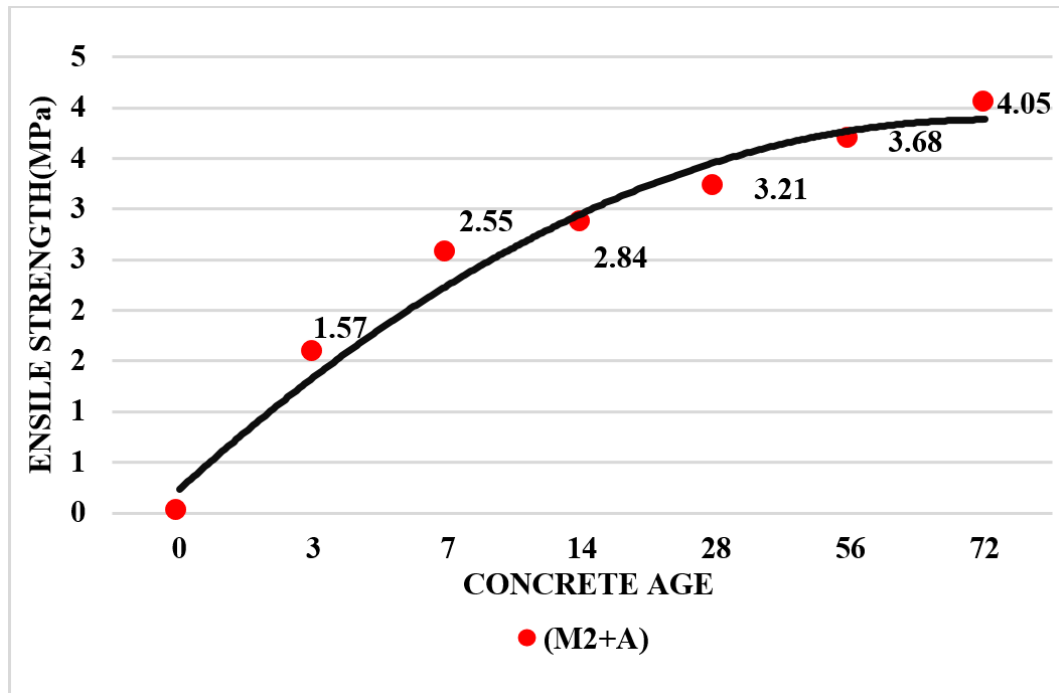


Figure 13. Air-entrained tensile strength development

3.9. Tensile Strength in Air-Entrained Samples Subjected to Freezing and Thawing (M2+A+FT)

Figure 14 shows the experimentation of cylindrical specimens incorporating air into the sample (M2+A+FT), which showed that the tensile strength at 28th day reached a value of 3.07 MPa, the samples at 56th day increased to 3.45 MPa and after 72 days they reached a resistance of 3.31 MP.

3.10. Tensile Strength Comparison

Figure 15 shows the results of the tensile strength of (M2), (M2+A), (M2+FT), (M2+A+FT), (M2+A+FT) at 3, 7, 14, 28, 56 and 72 days, where the sample (M1) increased its tensile strength up to 59.87 % at 72nd day with respect to the design strength of 3.04 MPa, likewise, the same sample (M2) increased its tensile strength up to 46.05 % at 56th day with respect to the design strength of 3.04 MPa, thus surpassing the other samples for the ages of 56 days and 72 days.

3.11. Representation of the Regression Equation

Independent variables such as tensile strength (TS), air incorporation (AI), subsection to freezing and thawing (FT),

and finally, the number of days (D) of curing explain 98.2% of the variability of the independent variable compressive strength (C). Equation 3 shows the correlational equation of the experiment.

$$C = -15887 + (9.6445 * T) + (2.6253 * A) + (0.7436 * LT) + (-0.0012 * D,)$$

Figure 16 shows the representation of the normal linear regression, each point is real data.

3.12. Unit Price Analysis

Table 14 shows the unit price analysis for obtaining moraine aggregate per cubic meter in one day, where the equivalent cost amounts to 228.18 USD soles, with labor accounting for 32.67%, the cost of materials for 14.69% and equipment and tools for 52.64%.

3.13. Failure Modes

Figure 17 shows the fracture forms in the elaborated specimens, in which the most frequent failure mode in the specimens when applying gradual loads experienced columnar failure, columnar cone failure and bottom shear failure.

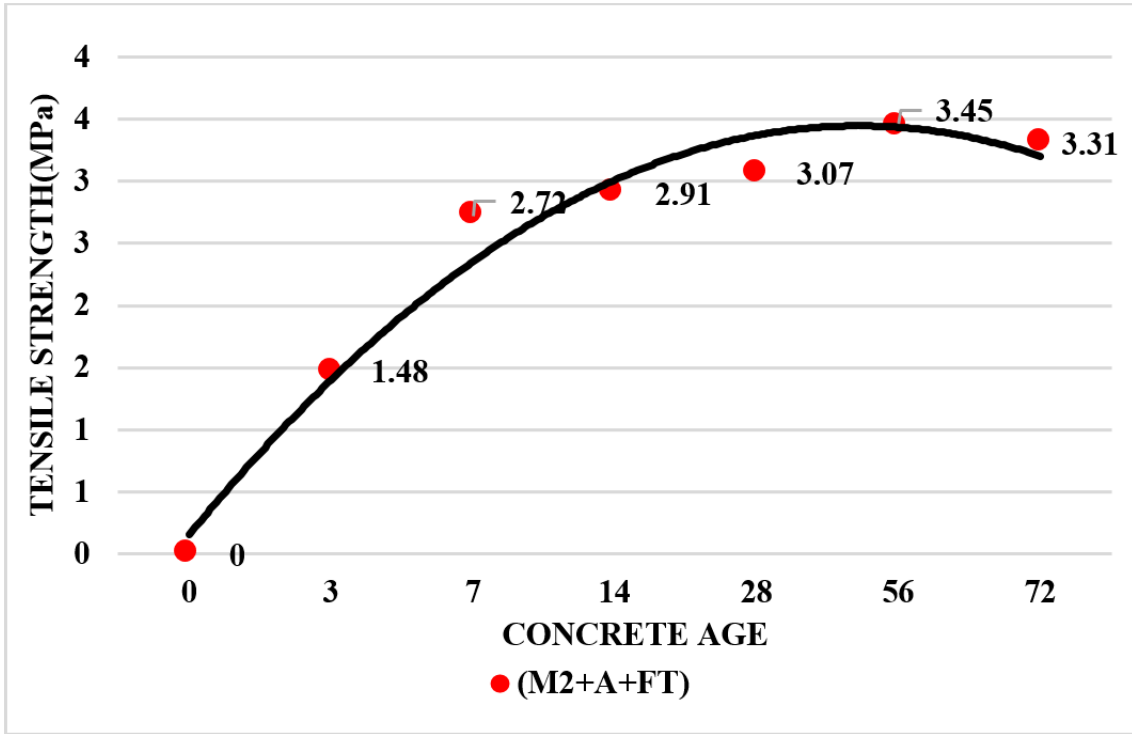


Figure 14. Development of tensile strength with entrained air, subjected to freezing and thawing

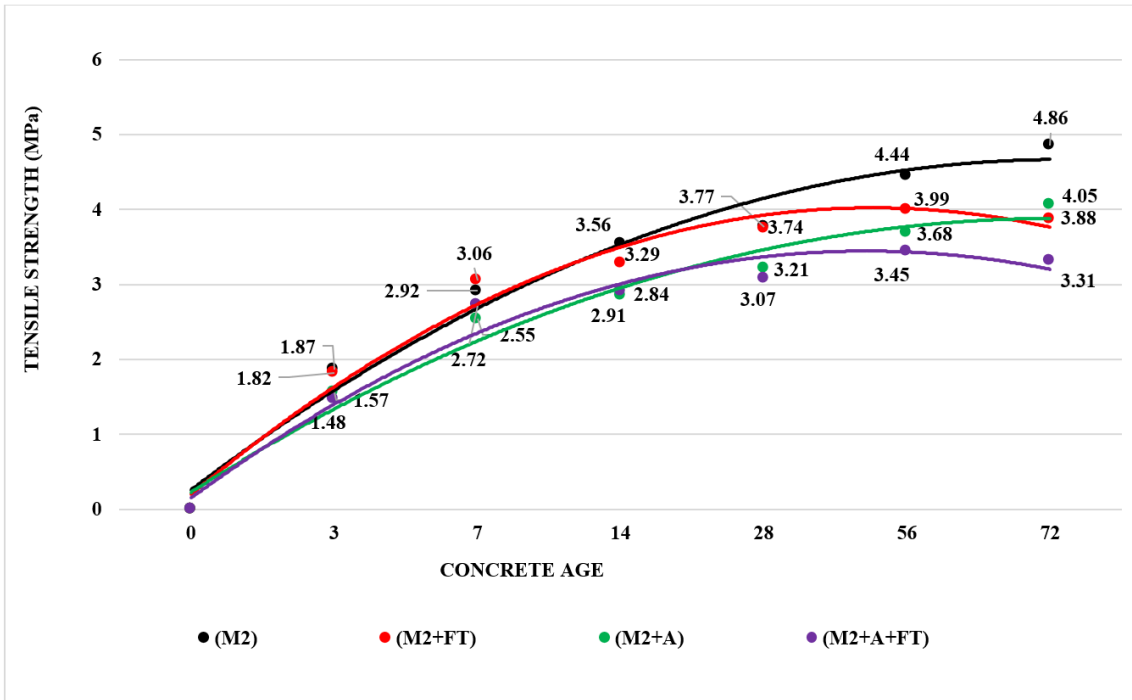


Figure 15. Summary of comparison of tensile samples

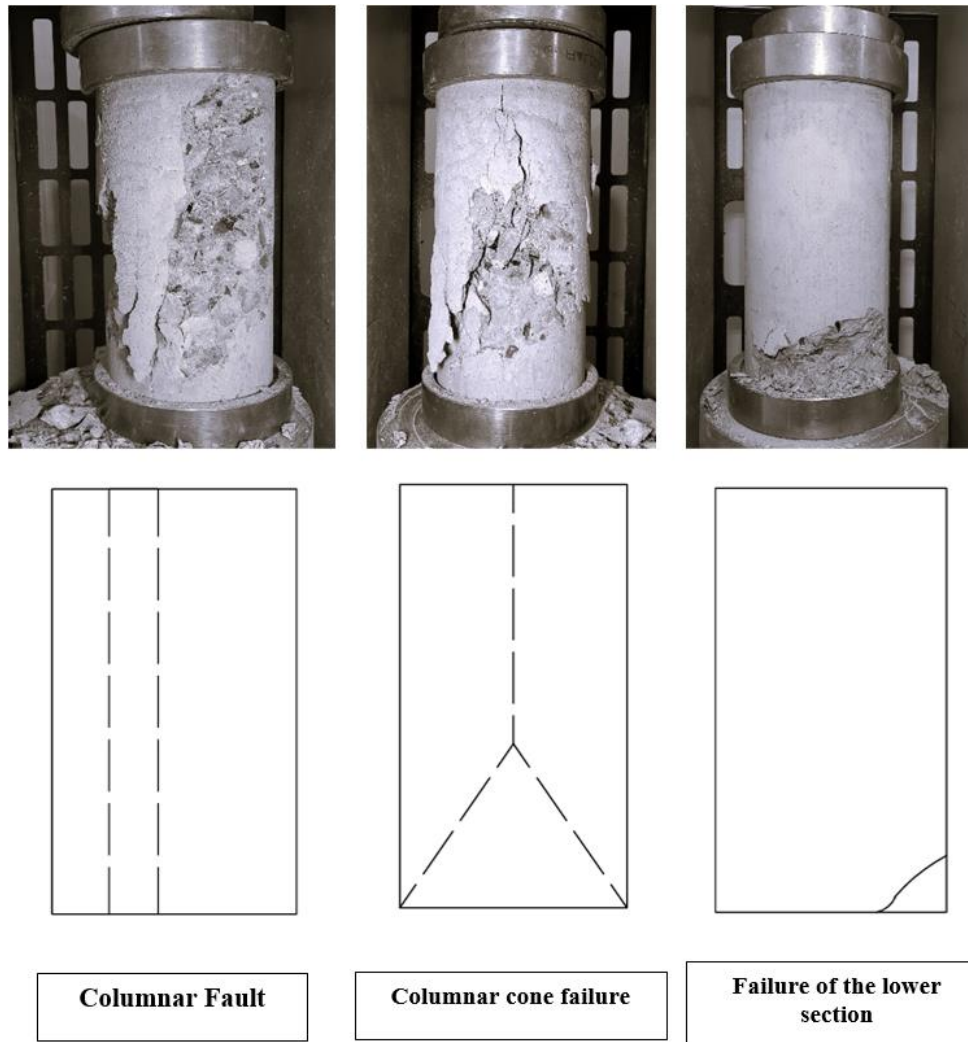


Figure 17. Specimen failure modes

4. Discussions

Despite the demonstrated potential of glacial aggregates in hot mix asphalt, there is also evidence supporting its potential for the realization of concrete manufacturing use, indicating an underutilization of these resources. Regarding the cost analysis, it could vary with fluctuations in the transportation and materials market [5]. The cost of obtaining moraine aggregate is similar to the cost of the coarse aggregate usually used, which ranges between 224.4 USD [26], however, most of the works carried out in the country are constantly executed in areas far from the city that lead to elevated spaces due to their topography and that makes it more affordable to extract from glaciers, helping to reduce the distance in the transportation of this material. The current situation of the investigation shows that there are reserves of moraine aggregate in central Peru, a viable alternative due to the prohibition of its use of natural aggregates of the rivers due to the predation of the banks of the Mantaro River.

The research focuses on a particular type of moraine

aggregate from the fourth ice age, which may not reflect the characteristics of other aggregates available in different regions [4]. Freezing and thawing cycles vary considerably depending on the climate. Therefore, the results obtained under the specific conditions of this study may not be applicable to other areas with different temperature and humidity samples [6].

In the present investigation, 44 freezing and thawing cycles were carried out on the specimens without incorporated air, of which they reached values greater than 100% of the design compression resistance of 30.41 MPa after 28 days, particularly the samples (M1) increase their resistance by up to 145% at 72 days and the specimens (M1+FT) increase their resistance by up to 111% at 72 days with respect to the design resistance as in the research [27], [28]. Dolomite was used as an aggregate for the samples, which with 50 cycles of freezing and thawing resulted in a gain in the compressive strength of the concrete of 110.5%, these values differing from the different type of aggregates that were used. However, the samples with incorporated air provide better workability and resistance to freezing and

thawing but reduce their compressive strength by up to 2.53%, since the water/cement ratio of the mixture design is affected, thus changing the amount of aggregate fine [29].

Similarly, for the tensile strength of the samples without air incorporation, they had values greater than 100% of the design resistance of 3.04 MPa after 28 days. This gain in resistance is due to changes in the physical properties of the sample as well as the conservation of its weight and heat capacity, since it is not altered by the water/cement ratio of 0.45 [30]. On the other hand, the samples (M2+A) increased their tensile strength by up to 133% and the samples (M2+A+FT) increased their resistance up to 113% after 56 days of experimentation, on the contrary in the samples (M2+A+FT) that were reduced by 27.63% after 72 days, like the research carried out [31] where the tensile strength is reduced and guarantees the resistance to thawing in the samples. Figure 18 shows the breaks in the beams. However, it is necessary to carry out long-term studies to confirm the durability and effectiveness of concrete under various environmental and use conditions [1].



Figure 18. Result of the tensile strength test failure

Finally, the results of compression and tensile samples both with incorporated air and air without incorporation showed increasing proportional values up to 72 days, however, it should be taken into consideration when subjecting them to freezing and thawing since they do not usually present the same behavior. This behavior is attributed to the activation of the pores of the concrete, giving a sign of resistance to temperature change, but if this is constant for long periods of time, it causes pressures on its walls that affect its resistance and gives rise to the process called weathering [32].

5. Conclusions

The moraine aggregate from the fourth glaciation is an excellent alternative for the manufacture of structural concrete. In this research, it was shown that it improves compressive and tensile strength despite attacks due to freezing and thawing, in reference to design resistances. Furthermore, this type of concrete is characterized in Peru as high resistance concrete. According to the compressive

strength results, this concrete without the addition of any additive and under normal conditions reaches up to 44.13 MPa, however, when subjected to areas with low temperatures in the mountains of Peru that are prone to freezing and thawing, it reaches up to a resistance of 31.18 MPa. The compressive strength was higher than the design compression strength (30.41 Mpa).

Next, the moraine aggregate contributes efficiently to its tensile strength, thus reaching a value of 4.86 MPa under normal conditions and with the incorporation of air subjected to freezing conditions it reached 3.31 MPa. The tensile strength was higher than the tensile design strength (3.04 MPa).

Based on the use of the moraine aggregate from the fourth glaciation that is found at altitudes greater than 3000 meters above sea level, it is recommended to evaluate the economic feasibility of obtaining it, as well as to study the fracture forms under different force loads.

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