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Influence of Calcined Diatoms on the Properties of Conventional Concrete

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Abstract

Today, the construction industry has expressed its preference for the use of sustainable materials due to the significant impact they have on the environment. Although concrete is widely used in construction due to its diverse properties, one of its main components, known as clinker, is a major contributor to CO2 pollution. Therefore, the feasibility of partially replacing this material with alternatives is being investigated. Among them, calcined diatoms are presented as a promising option. These are an extremely fine and highly porous material, composed mainly of silica, which has a large specific surface area. The abundant presence of active silica improves the properties of concrete, such as its strength, while the ultrafine particles of diatoms densify the concrete structure, thus achieving a concrete with greater durability. The objective of this study was to evaluate the properties of conventional concrete, both fresh and hardened, by adding calcined diatomite in proportions of 5%, 10% and 15%, with the purpose of determining the optimum percentage of calcined diatomite to achieve adequate concrete development. Test specimens were elaborated without the addition of calcined diatoms and with the addition of calcined diatoms, then immersed in water for 7d, 14d and 28d. Tests were carried out in the fresh state to obtain workability, bleeding, setting time, air content, temperature, and unit weight. In the hardened state, tests were carried out to obtain compressive strength, static modulus of elasticity and permeability. It was found that with a lower addition of calcined diatomaceous earth, the concrete can develop as a normal concrete, and improvements in compression were obtained, increasing with respect to the control concrete. However, by increasing the percentage of calcined diatomite, the workability is reduced and in general, the properties do not show an improvement. Concrete with the addition of calcined diatomite can be used as a thermal insulator, since it presents very fine particles that perform a filling effect, densifying the concrete matrix, and it can also be used for lightweight concrete since it reduces 17kg/m3. On the other hand, the compressive strength with 5% calcined diatomite increased by 9% with respect to the standard, due to its high pozzolanic activity. In addition, a lower permeability was found with the addition of 5% calcined diatomite. In general, calcined diatomite in lower proportions can generate resistant and durable concrete.

1. Introduction

The construction industry has been adopting the use of sustainable materials due to their environmental impact. This situation has generated the need to manufacture materials with sustainable products. Although concrete is widely used in construction due to its strength, workability, adaptability, durability and fire resistance, its production causes significant pollution due to CO2 emissions. In addition, the extraction, production and transportation of mineral materials, as well as water consumption, contribute to the depletion of natural resources and the generation of greenhouse gases. For example, Portland cement production produces between 700 and 1,000 kg of CO2 emissions per ton of clinker (Cachim et al., 2014).

In order to address the negative impact of Portland cement production on the environment, the possibility of partially replacing this material with supplements or additives is being explored. In fact, it has been shown that replacing Portland cement with other materials can improve concrete performance. One such material is diatomaceous earth, a sediment composed mainly of layers of diatoms. This material is very fine, rich in silica, highly porous and has a large surface area. It is usually calcined to remove organic matter before being marketed, and its properties make it suitable as a cement substitute (Cachim et al., 2014).

In Brazil, the effect of the addition of diatomite on the characteristics of concrete was studied, with the objective of reducing CO2 emissions during cement production. Concentrations of 5% and 10% of diatomite in cement were analyzed to determine their influence on concrete (MacEdo et al., 2020).

As mentioned above, diatomites are a type of siliceous rock composed mainly of SiO2. Calcination of diatoms significantly improves the strength, durability, and other properties of concrete. The presence of a large amount of active SiO2 and the specific surface area of diatoms (5.8 times higher than that of Portland cement according to studies (Pokorny et al., 2019)) play a key role in improving the strength of concrete. The addition of diatomite can significantly increase the amount of C-S-H in the final hydration phase of cement (after 28 days) (Du, 2019). In addition, the ultrafine particles of diatomaceous earth fill the voids, which, together with the calcium hydroxide produced by the chemical reaction between cement and water, makes the concrete structure denser. This additive also creates a chemical bond that prevents the penetration of aggressive substances into the concrete, despite the increased porosity.

The present investigation is carried out with the purpose of examining the behavior of a conventional concrete with a characteristic strength f'c of 210 kg/cm2 in the fresh state and hardened by adding different proportions of calcined diatomite: 5%, 10% and 15%. In the fresh state, aspects such as slump, setting time, temperature, air content, bleeding and unit weight will be evaluated. In the hardened state, the compressive strength, modulus of elasticity and permeability of the concrete will be analyzed. The objective of these tests is to determine the optimum percentage of calcined diatomite that will allow an adequate development of the concrete.

2. Experimental Work

2.1 Materials

The materials used in the preparation of the concrete, both the fine aggregate and the coarse aggregate, complied with the limits established by (ASTM C33,1999). Also, Type I cement was chosen since it was the most appropriate for observing the effects of calcined diatomite on the test results. The granulometric curves of the aggregates are provided in Fig 1.

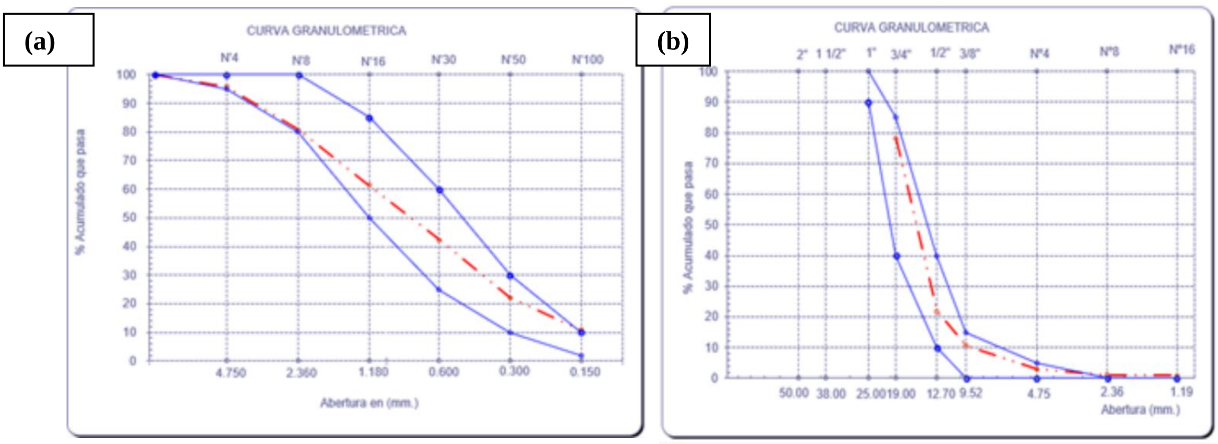

Fig. 1 *(a) Granulometric curve of fine aggregate, (b) Granulometric curve of coarse aggregate*

Only calcined diatomite was used as an addition, no additional plasticizer or superplasticizer additives were used for this research. The chemical analysis and physical properties of the calcined diatomite are provided in Table 1 below:

Table 1 *Physical Properties and Chemical Analysis*

Content (%)	Chemical	Physical
SiO_2	91.4	-
Al_2O_3	3.8	-
Fe_2O_3	1.9	-
P_2O_5	0.2	-
TiO_2	0.2	-
CaO	0.6	-
MgO	0.2	-
$Na_2O + K_2O$	1.2	-
Color	-	Pink
Appeareance	-	Powder
Permeability,Darcys	-	0.09
Wet Density(g/L)	-	307
pH	-	5.2
Specific Gravity	-	2.1

2.2 Concrete Mixes

The concrete preparation was divided into four batches. The first batch had no calcined diatoms, but the second batch replaced 5% (M1) of the cement weight with calcined diatoms. The third batch replaced 10% (M2) of the cement weight and the last batch replaced 15% (M3) of the cement. In addition, 3/4-inch coarse aggregate was used. The mix designs were performed using the (ACI 211, 2001) method and the calculated proportions are provided in Table 2 for all mix designs based on a concrete volume of 1 m3. A mechanical drum mixer with a capacity of 140 L and operated by electric current was used. It is important to note that each batch of concrete was mixed for approximately 5 minutes.

Table 2 *Concrete mix details (kg/m3)*

Proportion	Control Mix	Mix with 5% (M1)	Mix with 10% (M2)	Mix with 15% (M3)
Cement	382.88	363.736	344.592	325.448
CD	-	19.144	38.288	57.432
Fine aggregate	727.66	727.66	727.66	727.66
Thick aggregate	985.76	985.76	985.76	985.76
Water	215.9	215.9	215.9	215.9

2.3 Casting and Curing

Procedure established by (ASTM C31, 2008). Specimens were prepared by filling them in three layers with applications of 25 bars and 15 compactions per layer. After 24 hours, the mold was removed, and the specimen was placed in place for curing. Subsequently, the samples were analyzed at 7, 14 and 28 days. Using the immersion method, the samples are immersed in a pool of concrete for curing. For each concrete mix, 9 samples were prepared for compressive strength tests and 6 samples for permeability tests, since, for durability tests, it was evaluated with the best addition of calcined diatom. The dimensions of these samples were 15 cm in diameter and 30 cm in height.

2.4 Testing Procedure

2.4.1 Slump Test

The slump test was performed in accordance with the standard procedures specified in (ASTM C143,2010). An Abrams cone was used for the tests. Twenty-five bar blows were applied to each third of the concrete specimens, except for the last layer. In the last layer, 15 bar strokes were first made, then more concrete was added just above the edge of the cone, and then another 10 bar strokes were made to complete the required 25 strokes. The Abrams cone is then taken vertically, and the slump of the concrete is measured. This procedure was performed for each concrete mix. The procedure performed in the laboratory is provided in Fig 2.

Fig. 2 *Slump Test*

2.4.2 Bleeding Test

This test followed a standardized procedure established by (ASTM C232, 2009). The specimens were filled in three layers and 25 bar blows and 15 blows with the rubber mallet were applied to each layer. In the last layer, the molds were filled, leaving approximately 1 inch of free surface. Subsequently, measurements of the bleeding of the mixture were carried out every 10 minutes for the first 40 minutes, and then every 30 minutes until bleeding was completely stopped. A rod was used as an aid for convenient water removal. In addition, plastic was placed on top of the molds to reduce water loss by evaporation. This procedure was performed for each concrete mix.

2.4.3 Unit Weight Test

The procedure used to determine the concrete unit weight follows the guidelines of (ASTM C138, 2017). Before starting to fill the mold, the weight of the mold was recorded for later calculations. The mold was filled in three rounds, each round with 25 strokes using a rod and compacted with 15 strokes using the rubber mallet. After each layer, the mold was leveled and cleaned. Once the process is completed, the mold containing the concrete is weighed to obtain its unit weight.

2.4.4 Temperature Test

This test followed a standardized procedure established by (ASTM C1064, 2012). Fill the probe so that the temperature unit can sink into the concrete at least 3 inches. The device is then immersed in the concrete for a minimum period of 5 minutes, and the temperature reading is recorded.

2.4.5 Time of Setting Test

This test uses a process created by (ASTM C403, 1999). First the mortar was obtained by passing the concrete mix through a #4 sieve. This is done to remove any stones that may interfere with the reading results. Then 25 blows were given with the rod and 15 blows with the rubber mallet to compact the mortar. The mixture is left to set for the mortar to set for 3 to 4 hours before testing begins. Finally, a needle penetration test is performed every 30 minutes until the concrete has fully set.

2.4.6 Air Content Test

This test uses a process created by (ASTM C231, 2014). First, a container was filled with concrete in three layers, following the procedure described in the regulations. Next, the purge valve was opened, and water was injected from one side until it began to flow out of the other side. Then, the bleed cock and air valve were closed, and air was pumped in until the meter marked its initial position. To stabilize the meter, it was given small shocks and then the main air valve was released to take the test reading. The procedure performed in the laboratory is provided in Fig 3.

Fig. 3 *Air Content Test*

2.4.7 Compressive Strength Test

This test followed a standardized procedure established by (ASTM C39, 2014). First, the specimen axis was aligned with the center of the testing machine. Next, a constant load was gradually applied until a failure pattern began to be observed in the specimen. At that time, the reading of the applied load at the breaking point was recorded. Then, based on the data obtained, the strength is calculated. Specimens were tested after 7, 14 and 28 days for all proposed dosages for a more accurate monitoring of concrete strength development over time. The procedure performed in the laboratory is provided in Fig 4.

Fig. 4 *Compressive Strength Test*

2.4.8 Modulus of Elasticity Test

This test followed the standardized procedure established in (ASTM C469, 2002). In this case, the test was performed when the sample was 28 days old. First, the specimen is combined with an equipment to measure longitudinal deformation. Then aligned the specimen axis with the center of the testing machine. Then the load was gradually applied. During the test, when the deformation reaches 50 parts per million, readings of the applied load and longitudinal deformation are taken. In addition, the deflection is recorded when the load reaches 40% of the ultimate load. This data will be used in subsequent calculations. The procedure performed in the laboratory is provided in Fig 5.

Fig. 5 *Modulus of Elasticity Test*

2.4.9 Permeability Test

The test is carried out according to the standardized procedure (UNE-EN 12390, 2001). Samples with a diameter of not less than 15 cm are prepared. After the sample is prepared, it is abraded with a wire brush and subjected to water pressure. The samples shall be subjected to a pressure of 50 kPa for 3 days. After this time, the surfaces exposed to the water pressure are cleaned to remove excess water. The sample is then split into two parts perpendicular to the surface over which the water pressure is applied. The maximum depth to which the water penetrates is measured and rounded to the nearest millimeter. The procedure performed in the laboratory is provided in Fig 6.

Fig. 6 *Permeability Test*

3. Results and Discussion

3.1 Slump Test

In the slump test, a gradual decrease in the slump level could be observed as the percentage of calcined diatomite addition increased. This decrease is due to the highly porous nature of diatomite, which tends to absorb water. For example, the standard mix showed a slump of 10 centimeters, while with 5% addition a slump of 6.88 centimeters was obtained, with 10% a slump of 1.88 centimeters, and with 15% no slump was recorded. These results agree with the findings of (MacEdo et al., 2020) who also observed a reduction in settlement as the calcined diatomaceous earth content increased. In his study, the standard mix had a slump of 7.5 centimeters, while with a 5% addition a slump of 5 centimeters was obtained, and with 10% a slump of 4 centimeters. (Rodriguez et al., 2021) also investigated the use of diatomaceous earth in percentages of 5% and 15% in relation to the weight of cement and obtained similar results in terms of slump. For the control mix, he recorded a slump of 1 centimeter, while with an addition of 5% it remained at 1 centimeter, and with 15% a value of 0 centimeters was reached, i.e., no slump. These results support the conclusion that as the percentage of calcined diatomite increases, there is a decrease in the level of slump in the concrete. This is due to the porous properties of diatomite, which promote water absorption and affect the slump capacity of concrete. The results of the slump test are provided in Table 3.

Table 3 *Slump Test*

Concrete Mix	Slump(cm)
Control Mix	10
Mix with 5% (M1)	6.88
Mix with 10% (M2)	1.88
Mix with 15% (M3)	0

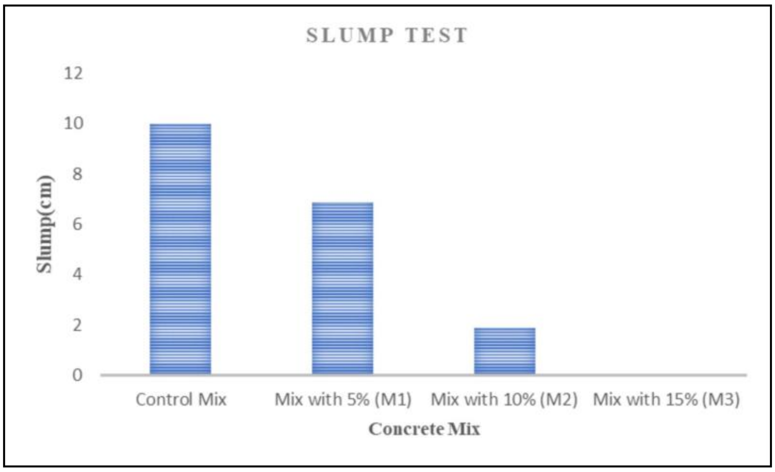

Fig. 7 *Slump Variation according to the proportion*

3.2 Bleeding Test

The results of the bleeding test are provided in Table 4. It was observed that as the percentage of calcined diatomite increased, the bleeding was reduced until reaching a value of 0%. For the standard concrete, the bleeding was 0.94%, while for 5% of calcined diatomite it was 0.77%, for 10% it was 0.62% and for 15% it was 0%. This is due to the fact that calcined diatom, being highly porous, has a greater water absorption capacity, which results in a decrease in bleeding. These results are in agreement with those obtained by (Hasanzadeh B & Sun Z, 2018) who also observed a decrease in the rate of concrete bleeding as the calcined diatomaceous earth content increased. In addition, the bleeding time was found to be reduced, as the standard, 2% and 6% samples stopped bleeding after 120 minutes, while the sample with 10% calcined diatomite showed less bleeding, indicating an inverse correlation between calcined diatomite content and concrete bleeding.

Table 4 *Bleeding Test*

Concrete Mix	Percentage of water bled
Control Mix	0.94
Mix with 5% (M1)	0.77
Mix with 10% (M2)	0.62
Mix with 15% (M3)	0

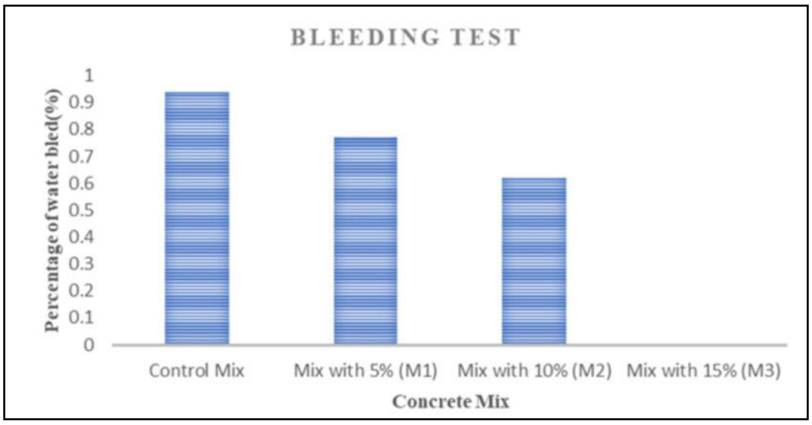

Fig. 8 *Mix Bleed*

3.3 Unit Weight Test

The results of the unit weights obtained are provided in Table 5. As more diatomite was added to the concrete, the concrete lost weight per cubic meter. This reduction is due to the fact that diatomite is a lightweight material and has a density much lower than that of concrete. For standard concrete a value of 2415.760 kg/m3 was obtained, while for 5% of calcined diatomite a unit weight of 2398.783 kg/m3 was recorded, for 10% it was 2389.352 kg/m3 and finally for 15% it was 2378.034 kg/m3. (Degirmenci & Yilmaz, 2009) in their study also found similar results. As the percentage of diatomite increased, the unit weight of the concrete decreased. For the control sample a unit weight of 2214 kg/m3 was obtained, while for 5% addition 2208 kg/m3 was recorded, for 10% addition it was 2146 kg/m3 and for 15% addition a unit weight of 2098 kg/m3 was obtained. (Mehmedi Vehbi GÖKÇE, 2012) found that unit weights with 10% diatomite percentage decreased up to 49% and samples with 40% substitution decreased up to 30% with respect to standard concrete. These results show that as the percentage of diatomite increases, it is possible to obtain lighter concretes.

Table 5 *Unit Weight Test*

Concrete Mix	Unit Weight(kg/m3)
Control Mix	2415.76
Mix with 5% (M1)	2398.78
Mix with 10% (M2)	2389.352
Mix with 15% (M3)	2378.034

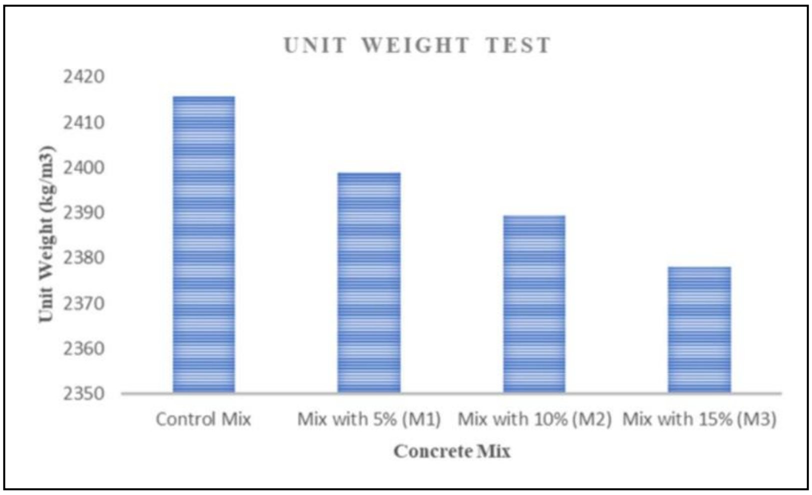

Fig. 9 *Variation of Unit Weight for each percentage of addition*

3.4 Temperature Test

The temperature results are provided in Table 6. For the standard concrete, a temperature of 22.9 °C was obtained, while for 5% calcined diatomite a temperature of 20.6 °C was recorded, for 10% it was 21.5 °C and for 15% it was 22.5 °C. A decrease in temperature can be observed with the addition of 5% calcined diatom, and as the percentage is increased, the temperature tends to increase. However, in all cases, the temperature of the concrete with diatomite addition is lower than that of the standard concrete. (Taoukil et al., 2021) addressed the issue of thermal conductivity and thermal diffusivity, noting that both decrease with the addition of diatomite. This improves the insulating capacity of the material, which is related to the intrinsic properties of diatomite. These findings support the results of the research, where a significant decrease in concrete temperature is observed with the addition of certain amounts of diatomite.

Table 6 *Temperature Test*

Concrete Mix	Temperature (C°)
Control Mix	22.9
Mix with 5% (M1)	20.6
Mix with 10% (M2)	21.5
Mix with 15% (M3)	22.5

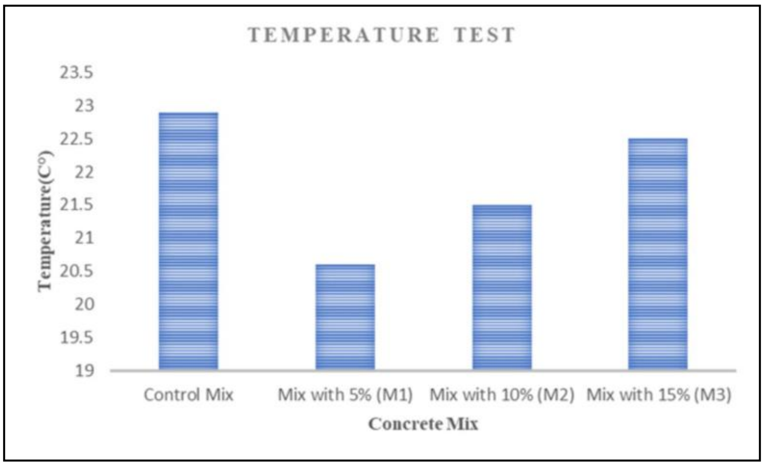

Fig. 10 *Temperature variation for each concrete mix*

3.5 Time of Setting Test

The results obtained for the setting time are shown in Table 7. It was observed that the standard concrete reached setting in 85 minutes, while for 5% of calcined diatomite a time of 82 minutes was recorded, and for 10% a setting time of 76 minutes was obtained. It was not possible to perform the test for 15% calcined diatomite because the concrete had a very dry consistency, which prevented following the procedure established by the standard.(Hasanzadeh B & Sun Z, 2018) in his research, also obtained similar results. For the standard concrete, the setting time was 182 minutes, while for 2% of calcined diatomite a time of 144 minutes was recorded, for 6% of diatomite a setting time of 141 minutes was obtained, and for 10% a setting time of 131 minutes was reached. These findings show that as the percentage of calcined diatomite increases, the setting time decreases. This phenomenon is due to the porous structure of the diatomite, which has the capacity to absorb the free water in the mixture, thus accelerating the setting process of the concrete.

Table 7 *Time of Setting*

Concrete Mix	Initial set(min)	Final set(min)
Control Mix	258	343
Mix with 5% (M1)	253	335
Mix with 10% (M2)	235	311
Mix with 15% (M3)	-	-

3.6 Air Content Test

Regarding air content, the results are provided in Table 8. This test was proposed by the author, and the following results were obtained. For the standard mix, an air content of 1% was recorded, while for 5% calcined diatomite a value of 1.3% was obtained, for 10% calcined diatomite a value of 1.7% was reached, and finally, for 15% an air content of 3% was obtained in the concrete mix. These results clearly indicate that as the percentage of calcined diatomite increases, an increase in air content is observed. This phenomenon can be attributed to the fact that calcined diatomite tends to absorb water from the mix, which decreases the workability of the concrete and hinders its proper compaction. As a consequence, a greater amount of air is retained in the material during the mixing and placing process. Therefore, a significant increase in air content is observed as the percentage of calcined diatomite in the concrete mix increases.

Table 8 *Air Content Test*

Concrete Mix	Air Content (%)
Control Mix	1
Mix with 5% (M1)	1.3
Mix with 10% (M2)	1.7
Mix with 15% (M3)	3

3.7 Compressive Strength Test

The results are provided in Table 9. The compressive strength test was carried out at 7d, 14d and 28d. For the standard concrete, results of 210 kg/cm2, 234 kg/cm2 and 241 kg/cm2 respectively were obtained, for 5% of calcined diatomite 190 kg/mc2, 228 kg/cm2 and 263 kg/cm2 respectively were obtained, for 10% 179 kg/cm2, 205 kg/cm2 and 226 kg/cm2 respectively, and for 15% of diatomite 164 kg/cm2, 190 kg/cm2 and 202 kg/cm2 respectively were obtained.(Du, 2019), who evaluated 10% and 20% of calcined diatomite, obtained the same concept, since at 7d and 28d for the standard concrete he obtained a resistance of 516 kg/cm2 and 578 kg/cm2 respectively; for 10% of calcined diatomite, he obtained a result of 614 kg/cm2 and 636 kg/cm2 respectively and for 20% of calcined diatomite the resistance decreased by 482 kg/cm2 and 556 kg/cm2 respectively.(Letelier et al., 2016) obtained similar results, for the standard concrete he obtained a resistance of 347.31 kg/cm2, for 5% he obtained resistance values of 372.71 kg/cm2, for 10% of diatomite 335.49 kg/cm2 and for 15% he obtained a value of 320.70 kg/cm2; obtaining better results for a lower proportion of diatomite.(Taoukil et al., 2021) used diatomite in mortars but obtained that as the amount of diatomite replacement increased, the compressive strength was reduced by 73.93%. (Abrão et al., 2019) made two mixtures with calcined diatomite, one ranging between 6%-14% and the other varying between 15%-50% of diatomaceous earth, for which a greater evolution of resistance was obtained in the first 7 days with the lower addition of diatomaceous earth, but then at 28 days and 91 days showed a greater increase in resistance due to the pozzolanic activity of the diatomite. (Bheel et al., n.d.) in his research with supplementary cementitious materials, observed that replacing 10% of cement with metakolin obtained a strength of 303.37 kg/cm2 at 28 days and with 20% obtained a lower strength of 244.73 kg/cm2, resulting in a greater increase in strength with respect to the standard concrete when replacing the cement with 10% of metakolin. (Pokorny et al., 2019) obtained similar results, for the standard concrete he obtained 551.67 kg/cm2, for 5% of calcined diatomite a resistance of 730.12 kg/cm2, for 10% a value of 682.19 kg/cm2, at 15% a resistance of 60.1% and for 20% a resistance of 668.93 kg/cm2; obtaining a better result for the lesser addition.(Kastis et al., 2006) observed that the development of compressive strength does not show great changes when the cement is replaced by 10% of calcined diatomite. However, a greater increase of calcined diatomite in the mix leads to cements with a lower strength than that 14.9of the standard concrete. (Rodriguez et al., 2021) shows that replacing 5% and 15% of diatomite in the cement gives values similar to those of the standard concrete. (Liu et al., 2021) for his research used 4% diatomite as a partial replacement of cement to avoid loss of compressive strength. (Xiao et al., 2012) when using 30% diatomite as a replacement for cement, presented a strength ratio of 74.8% at 28d compared to the standard mix, which had a ratio of 61.2% at 28d. (Zahalkova & Rovnanikova, 2016) also mentions that with the increase of the amount of diatomite the compressive strength decreases, obtaining that the most adequate replacement percentage is 10% of diatomite. However, (Degirmenci & Yilmaz, 2009) obtained for the control concrete a value of 508.53 kg/cm2 for 28 days, for 5% a value of 469.27 kg/cm2 for 10% a value of 253.20 kg/cm2 and for 15% a value of 152.35 kg/cm2. On the other hand, (Paiva et al., 2016) obtained better compressive strength results for concrete made with 8% and 10% diatomite.

There is an inverse relationship between the calcined diatomaceous earth content and the compressive strength of concrete. However, it is important to keep in mind that the results may vary depending on factors specific to each study, such as the type of diatomite used and the characteristics of the concrete itself. Therefore, it is necessary to perform a careful analysis and consider multiple factors when determining the optimum calcined diatomaceous earth content to achieve the desired concrete strength.

Table 9 *Compressive Strenght Test (kg/cm2)*

Concrete Mix	7d	14d	28d
Control Mix	210	234	241
Mix with 5% (M1)	190	228	263
Mix with 10% (M2)	179	205	226
Mix with 15% (M3)	164	190	202

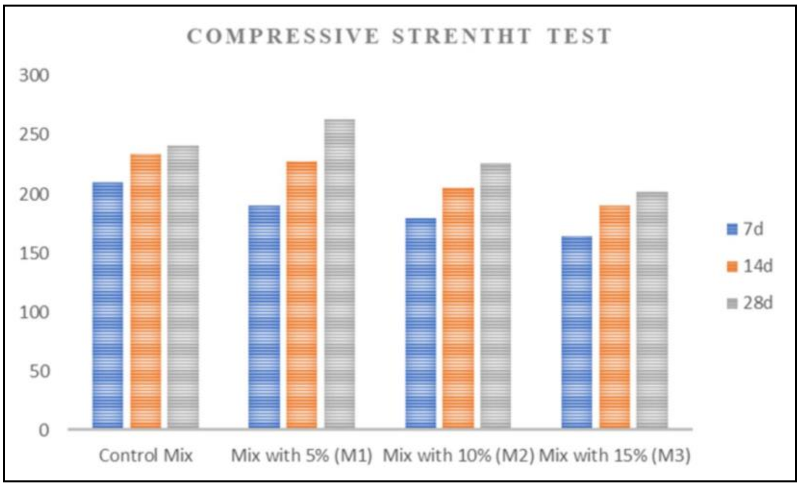

Fig. 11 *Concrete resistance for each percentage of addition at 7d, 14d, 28d*

3.8 Modulus of Elasticity Test

The results obtained are presented in Table 10. It was observed that by incorporating 5% calcined diatomite in the concrete mix, there was an increase compared to standard concrete. However, by increasing the percentage of diatomite to 10% and 15%, a decrease in the modulus of elasticity was observed in relation to the standard concrete. (Letelier et al., 2016) found similar results, who showed that by replacing 5% diatomite, the modulus of elasticity increased to 288400 kg/cm2, compared to 278800 kg/cm2 for the standard concrete. As the percentage of diatomite was increased to 10% and 15%, a reduction in the modulus of elasticity was observed.

Table 10 *Modulus of Elasticity Test*

Concrete Mix	Modulus of Elasticity(kg/cm2)
Control Mix	230898.02
Mix with 5% (M1)	234468.34
Mix with 10% (M2)	226067.36
Mix with 15% (M3)	202272.19

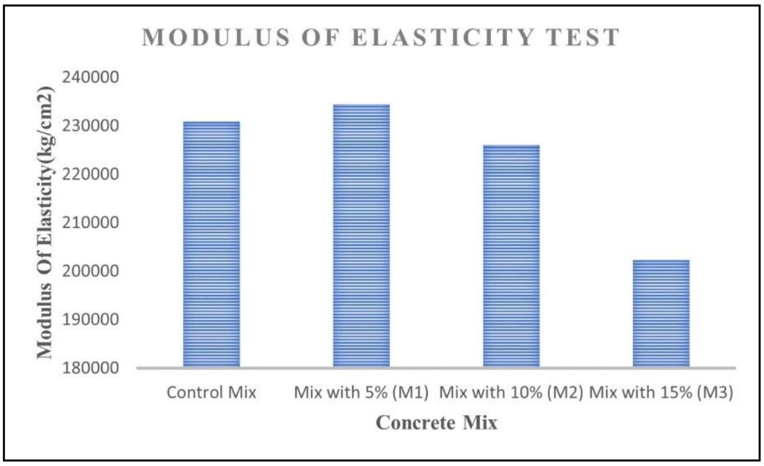

Fig. 12 *Variation of the Modulus of Elasticity for an age of 28 days*

3.9 Permeability Test

The results are provided in Table 11. Permeability tests were carried out and favorable results were obtained when calcined diatomite was added. The standard concrete showed a permeability of 36.3 mm, while when 5% calcined diatomite was added, a value of 32.5 mm was recorded, indicating a decrease in permeability. In previous investigations, (Bheel et al., n.d.) Used sedimentary materials and in all cases achieved a lower permeability than the control concrete. For example, when using metacolin, a lower permeability was observed when 20% of this admixture was added. These results support the idea that the incorporation of calcined diatomite results in a more impermeable concrete.

Table 11 *Permeability Test*

Concrete Mix	Permeability(mm)
Control Mix	36.3
Mix with 5% (M1)	32.5

4. Conclusions

Calcined diatomite has 91.4% silica and a high specific surface area, which allows it to work as a pozzolanic material, helping concrete to improve its properties, making it suitable to be used as a supplementary sedimentary material and thus contributing to the reduction of CO2 emissions from the production of clinker to make cement.

In its fresh state, calcined diatomite, due to its high porosity, absorbs water from the mix, reducing workability, and exudation and setting time. On the other hand, it can be used as a thermal insulator, since, having such fine particles, it acts as a filler, densifying the concrete matrix and lowering the temperature with respect to the control mix. In addition, it can be used for the elaboration of lightweight concrete since it decreased 17kg/m3 and as the percentage of diatomite increased, this value increased. The increase in air content is due to the loss of workability since it is more difficult to compact to eliminate air bubbles in the mixture as the percentage of diatomite increases.

In the hardened state, improvements were observed with respect to compressive strength. It exceeded the strength of the standard concrete with 5% calcined diatomite by 9%. However, as the percentage of diatomite was increased to 10% and 15%, this strength decreased even below that of the control concrete. It was observed that the concrete with 5% diatomite increased in strength at 28d, due to the high pozzolanic activity it contains. In the case of permeability, a more impermeable concrete was obtained with 5% calcined diatomite, obtaining a lower value than that of the standard concrete, because the calcined diatomite densifies the concrete matrix with its ultrafine particles, preventing the entry of external agents.

The calcined diatomite behaves better, and better results are obtained when it is applied in smaller proportions to the concrete, concluding that the optimum percentage for the concrete to develop correctly is 5%. In addition, improvements are obtained in compressive strength and permeability, which are some of the most important factors when manufacturing concrete.

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