Influence of Talc on Concrete Properties

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Abstract

Talc's effects on concrete water absorption and compressive strength were assessed. A PVC pipe was cut with a chop saw to create cylindrical molds. Each sample consisted of 135 g of water and 400 g of powder (cement powder and talc). Three levels of cement replacement ratios (0%, 10% and 20%) were considered. Samples were cured for three days and removed from molds using an arbor press. Water absorption was determined using the difference between the samples' mass before and after water submersion. Compressive strength was calculated by dividing the crushing force of the sample, measured using a UTM-3B machine, by the cross-sectional area of the sample. Talc-to-cement replacement ratios have a significant effect on water absorption (ANOVA, $F(2, 1)=21.839$, $p<0.02$) and compressive strength (ANOVA, $F(2, 1)=241.220$, $p<0.001$). Tukey's post hoc comparisons showed that mean scores for water absorption for 10% (20.200 ± 0.849 g) and 20% (20.700 ± 1.48 g) were significantly greater than 0% (13.875 ± 1.025 g), but did not significantly differ between each other. Mean score for compressive strength significantly decreased as talc percentage increased: 0% (3644.649 ± 67.524 psi), 10% (2291.831 ± 90.032 psi) and 20% (1671.127 ± 112.540 psi). Talc increased concrete water absorption until a certain point while compressive strength decreased as talc percentage increases. (Word Count: 200)

Introduction

Concrete is one of the most widely used materials in the world (Zheng, Lou, Du, Li, Liu, & Li, 2018). The most popular use of concrete is in roads and sidewalks, providing safe transportation for pedestrians and drivers alike. In addition, concrete is often implemented in roads and bridges because of its strong, water-resistant properties. Lastly, concrete is essential in the creation of everyday buildings and skyscrapers. However, infrastructure in the world, especially the United States, is constantly degrading and is in need of repair or replacement. As a result, the need for a strong, durable concrete is clear.

A major cause of concrete degradation over time is repeated freeze-thaw cycles. Freeze-thaw cycles are extremely common in cold, wet areas, where moisture tends to become trapped inside concrete and freeze, expanding within the concrete. These cycles can cause concrete scaling and harm to the concrete's structural integrity (Gyurkó, Szijártó, & Nemes, 2017). Past research reinforces this idea as water absorption and permeability have been inversely linked to scaling resistance (Wawrzeńczyk, Molendowska, & Kłak, 2016). It has also been shown that some fine powders, such as cellular concrete powder, can increase scaling resistance (Gyurkó et al., 2017). This is likely because many fine powders, including blast furnace slag and natural pozzolana, have the ability to decrease capillary water absorption of concrete (Deboucha, Oudjit, Bouzid, & Belagraa, 2015). Many fine powders' ability to reduce the pore size of concrete enables fine powders to decrease water absorption (Wawrzeńczyk et al., 2016).

Compressive strength is one of concrete's most important properties due to its primary purpose of supporting large amounts of force. The compressive strength of concrete normally ranges from about 3000 to 5000 psi. Compressive strength has also been shown to be directly linked to splitting tensile strength and flexural strength, two strong factors in determining a concrete's mechanical strength (Abid, Nahhab, Al-aayedi, & Nuhair, 2018). Earlier studies have reported that some fine powders, like marble powder, improve the compressive strength of concrete due to their ability to fit into spaces between the cement grains (Omar, Abd Elhameed, Sherif, & Mohamadien, 2012). However, some additives, such as recycled gravel, can decrease compressive strength (Fawzy, 2018). The strength and durability properties of concrete are heavily dependent on the angularity and size of concrete aggregate (Li, Khelifa, & El Ganaoui, 2017). In addition, the replacement ratio of additives is important to test because an excess of an additive, such as nanoclay, may harm the concrete's mechanical properties, even if a lower amount improved mechanical properties, due to the agglomeration of particles (Mohamed, 2016). Recycled concrete aggregate exhibited a similar trend as good results can be achieved through small amounts, but using 50% or more as a replacement may adversely affect the mechanical properties (Abid et al., 2018).

The production of cement powder releases large amounts of carbon dioxide, negatively impacting the environment (Popek & Sadowski, 2017). By substituting some cement powder with talc, less cement powder will have to be used and carbon dioxide emissions are indirectly lessened. Furthermore, talc is a very popular material used for a multitude of products, including baby powder, makeup, ceramics, paint, etc. Because talc is so widely used, there is an abundance of talc waste in the world. Waste that ends up in landfills greatly diminishes its yield and value as a potential renewable resource material for the manufacturing of new building products (Ulebeyli & Artir, 2015). Despite this, a large percentage of talc still remains unrecycled, so the addition of talc in concrete can help raise talc's yield and value while also reducing unnecessary carbon emissions released during the production of cement.

Talc is a hydrous silicate mineral with the chemical formula of $Mg_3Si_4O_{10}(OH)_2$ (Sabouang, Mbey, Liboum, Thomas, & Njopwouo, 2014). Talc has the characteristics of being hydrophobic, generally inert, and is the softest mineral on the earth. Compared to other silicates, talc is hydrophobic due to oxide surfaces, individual talc platelets are held together only by weak van der Walls forces (Fig. 1). Although it is hydrophobic, the edge surface is hydrophilic as a result of the –SiOH and –MgOH groups where the surface potential is pH dependent (Chauhan & Bhardwaj, 2017). Talc has been tested in concrete as a raw material in cement formulation with magnesium oxide (MgO) and as a super plasticizer for the formulation of cement poor concrete (Sabouang et al., 2014).

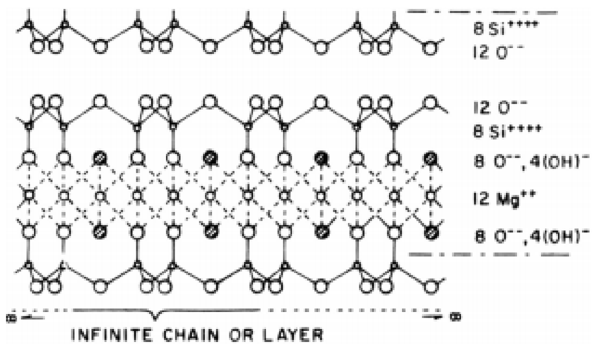

Figure 1 Molecular structure of pure talc mineral (Chauhan & Bhardwaj, 2017).

Concrete properties have been tested with many different additives, such as marble powder, rubber powder, clay, etc. However, there is little data on talc's effects on concrete properties. The current study aims to explore talc's direct effects on concrete properties, specifically water absorption and compressive strength. As a result, the talc-to-cement powder replacement ratios were altered.

Materials and Methods

Creation of concrete samples

For concrete molds, a PVC pipe was cut into six hollow cylinders with a diameter of 2 inches and a height of 4 inches using a chopsaw. Each cylindrical mold was lined with wax paper to prevent the cement from hardening to the inside of the mold. Wax paper was taped to the bottom of the mold to stop any cement powder, talc, or water from leaking out. Each concrete sample consisted of 135 g of water and 400 g of dry powder (cement powder and talc). Three groups of concrete with different talc-to-cement replacement ratios were used: 0, 10, 20%. The mixture distributions are depicted on Table 1. To create each sample, a container was filled up with 135 g of water and then the dry powders were added while mixing. Each mixture was then poured into a cylindrical mold. Two concrete samples were created for each group, totaling six concrete samples. Samples were cured for a period of three days at 23°C to ensure proper structural integrity. After curation, an arbor press machine was used to push the concrete samples out of their individual molds. The wax paper from the sides and bottom of the concrete sample was removed.

Table 1 Mix distributions for each cylinder (created by student researcher).

	Water	Cement Powder	Talc
0% Talc	135 g	400 g	0 g
10% Talc	135 g	360 g	40 g
20% Talc	135 g	320 g	80 g

Water absorption test

As shown in Figure 2, a watertight container was filled up to a water level of 3 inches. Each concrete sample was massed using an analytical balance in order to obtain an initial mass reading. All six samples were placed sideways into the water, so that they were all fully submerged. After being submerged for four days, each sample was towel dried and massed to find the final mass. The

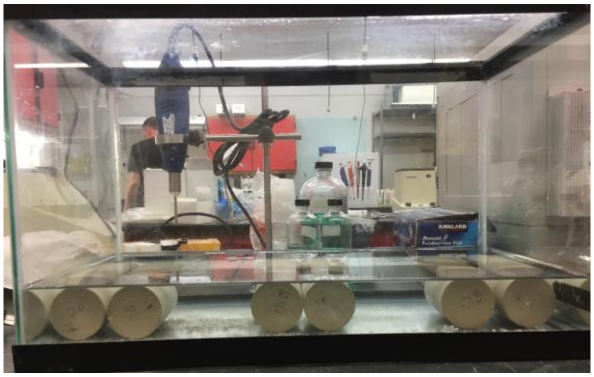

Figure 2 Concrete samples submerged in water (created by student researcher).

amount of water absorbed was determined by subtracting the final mass by the initial mass (Deboucha et al., 2015). Comparisons among the three replacement ratio groups were done using one way ANOVA with Tukey’s post hoc test.

Compressive strength test

Each concrete sample was tested for compressive strength using a UTM-3B compression testing machine. As shown in Figure 3, concrete samples were placed in the machine and endured a gradually increasing amount of force (Gerges, Issa, & Fawaz, 2018). The concrete samples were compressed until failure as pictured in Figure 4. The greatest amount of force sustained before the concrete sample failed was recorded. Compressive strength was calculated by dividing the greatest amount of force sustained by the cross-sectional area of each cylinder. Comparisons among the three replacement ratio groups were done using one way ANOVA with Tukey’s post hoc test.

Figure 3 Compression testing setup (created by student researcher).

Figure 4 10% talc-concrete sample after failure (created by student researcher).

Results

Creation of Concrete Samples

Each concrete sample cured for the three days and was cleanly removed from their respective molds using an arbor press machine.

Water Absorption Test

As shown in Table 2, the control, 0% talc-to-cement replacement ratio, group had an initial mass of 404.450±2.192 g, a final mass of 418.325±1.167 g, and a difference of 13.875±1.025 g. The 10% talc-to-cement replacement ratio group had an initial mass of 403.725±2.015 g, a final mass of 423.925±1.167 g, and a difference of 20.200±0.849 g. The 20% talc-to-cement replacement ratio group had an initial mass of 403.400±4.313 g, a final mass of 424.100±5.798 g, and a difference of 20.700±1.485 g. The average difference in mass for the 0% talc-to-cement replacement ratio group was lower than both the 10% and 20% talc-to-cement replacement ratio groups as seen in Figure 5. Comparisons among the three talc-to-cement replacement ratio groups done using one way ANOVA revealed that they were significantly

Table 2 Data for water absorption test found using an analytical balance (created by student researcher).

	Initial Mass	Final Mass	Difference
0% (1)	402.90 g	417.50 g	14.60 g
0% (2)	406.00 g	419.15 g	13.15 g
10% (1)	405.15 g	424.75 g	19.60 g
10% (2)	402.30 g	423.10 g	20.80 g
20% (1)	406.45 g	428.20 g	21.75 g
20% (2)	400.35 g	420.00 g	19.65 g

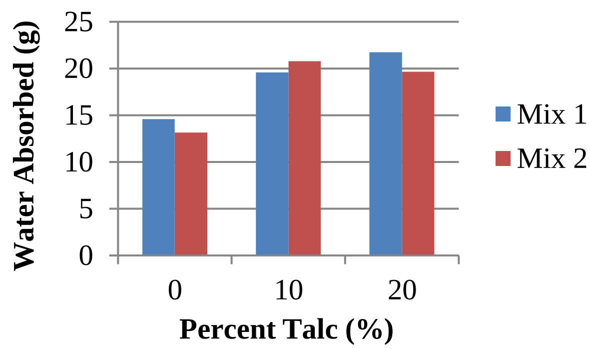

Figure 5 Graph of mass of water absorbed for each individual concrete sample (created by student researcher).

different (F(2, 1)=21.839, p<0.02). Post hoc comparisons using the Tukey HSD test indicated that the mean scores for the 10% and 20% talc-to-cement replacement ratio group were significantly greater than the 0% talc-to-cement replacement ratio group. However, the 10% and 20% talc-to-cement replacement ratio groups did not significantly differ from each other.

Compressive Strength Test

As shown in Table 3, the control, 0% talc-to-cement replacement ratio, group was able to withstand 11450±212.132 pounds of force, resulting in a compressive strength of 3644.648±67.524 psi. The 10% talc-to-cement replacement ratio group was able to endure 7200±282.843 pounds of force, resulting in a compressive strength of 2291.831±90.032 psi. The 20% talc-to-cement replacement ratio group was able to take 5250±353.553 pounds of force, resulting in a compressive strength of 1671.127±112.540 psi. As seen in Figure 6, the average compressive strength decreases as the percent of talc increases. Comparisons among the three talc-to-cement replacement ratio groups completed using one way ANOVA showed that they were significantly

Table 3 Data for compressive test found using a UTM-3B compression testing machine (created by student researcher).

	Crushing Force (lb)	Cross-sectional Area (sq. in.)	Compressive Strength (psi)
0% (1)	11300	3.142	3596.902
0% (2)	11600	3.142	3692.395
10% (1)	7000	3.142	2228.169
10% (2)	7400	3.142	2355.493
20% (1)	5000	3.142	1591.549
20% (2)	5500	3.142	1750.704

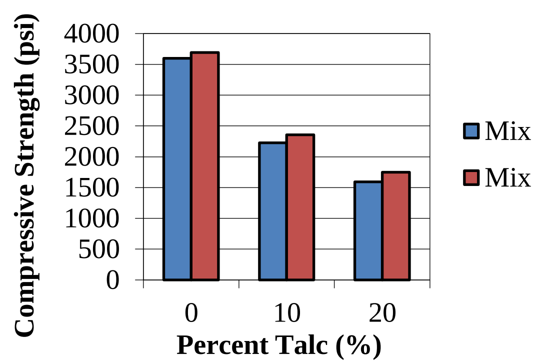

Figure 6 Graph of compressive strength for each individual concrete sample (created by student researcher).

different ($F(2, 1)=241.220$, $p<0.001$). Tukey's HSD post hoc comparisons revealed that each group was significantly different from one another. The 20% talc-to-cement replacement ratio group was significantly greater than the 10% and 0% talc-to-cement replacement ratio groups. Also, the 10% talc-to-cement replacement ratio group was significantly greater than the 0% talc-to-cement replacement ratio group.

Discussion

Creation of Concrete Samples

The concrete samples cured well in the 3 days of curation due to the fast-curing property of the multipurpose cement powder used. The samples slid out of their respective molds very smoothly and without any cracks or breaks largely because the wax paper lining prevented the concrete from hardening on the side of the cylindrical. In addition, the two-inch diameter of the cylindrical mold helped because the steel ram of the arbor press (1 in x 1 in) was able to fit through easily.

Water Absorption Test

The large difference in water absorption between the 0% (13.875±1.025 g) and 10% (20.200±0.849 g) talc-to-cement replacement ratio groups reveal that the addition of talc did in fact increase water absorption. However, the tiny increase in water absorption between the 10% (20.200±0.849 g) and 20% (20.700±1.485 g) talc-to-cement replacement ratio groups indicates that the increase in water absorption due to talc levels off at a certain point. As a result, a talc-to-cement replacement ratio more than about 10% for the purpose of increasing water absorption is useless as the increase in water absorption is minimal. This trend exhibited in talc is different from that observed in other fine powders, like natural pozzolana and blast furnace slag, which had a downward trend in water absorption as the addition of fine powder increased (Deboucha et al., 2015). Talc-concrete samples may have absorbed more water because talc is able to absorb moisture due to its hydrophilic edge surface (Chauhan & Bhardwaj, 2017). The talc-concrete samples can be inferred to have higher permeability and lower scaling resistance due to their increase in water absorption (Wawrzeńczyk et al., 2016).

Compressive Strength Test

The compressive strength decreased as the talc percentage increased across all three talc-to-cement replacement ratio groups: 0% (2291.831±90.032 psi), 10% (2291.831±90.032 psi), and 20% (1671.127±112.540 psi). This trend seen in talc differs from other studies for concretes with fine powder additives, such as powdered cellular concrete, which showed increased compressive strength with more powder additive (Gyurkó et al., 2017). However, the trend fits into some studies with additives, like recycled gravel, which demonstrated a decrease in compressive strength with more concrete additive (Fawzy, 2018). Talc's compressive strength trend could be a result of talc's soft characteristic (Chauhan & Bhardwaj, 2017). The soft nature of the talc particle may have resulted in the concrete experiencing stress fractures, as seen in Figure 7, more easily. Also, the trend may be due to the agglomeration of particles and inadequate distribution of particles while mixing (Mohamed, 2016). To adequately distribute particles, the cement powder and talc should have been mixed in their dry state using a standard drum-type mixer until the mixture became homogenous. Then, the water should have been added to the rotating mixer until homogeneity

Figure 7 20% talc-concrete sample after failure (created by student researcher).

was achieved (Omar et al., 2012). Based on the decrease in compressive strength due to the addition of talc, it can be inferred that talc-concrete samples have a lower splitting tensile strength and flexural strength (Abid et al., 2018).

Future Research

Different Replacement Ratios

In this study, the only talc-to-cement replacement ratios used were 0%, 10% and 20%. The inclusion of more replacement ratios may assist in creating more accurate conclusions. In addition, a wider range of replacement ratios may help to pinpoint the best and worst replacement ratios for each specific test.

Scaling Resistance Test

A very important property for concrete used in bridges and dams is scaling resistance. This is because freeze-thaw cycles have been shown to cause scaling, effectively degrading the structural integrity of the concrete (Gyurkó et al., 2017). A scaling resistance test can be done by placing samples with differing talc-to-cement replacement ratios into a temperature controlled set at -5 °C for 17 hours, then at 23°C for 7 hours (Kosior-Kazberuk, 2013). This can be repeated 50 times to imitate freeze-thaw cycles. After every five cycles, the surface of each concrete sample can be rinsed with water into individual watertight containers until all loose particles are removed. Each of the individual water solutions can be centrifuged in test tubes. The supernatant can be discarded and the scaling residue pellets can be extracted and massed using an analytical balance. The mass of the scaling residue pellets can be compared among groups with different replacement ratios.

Three-point Bending test

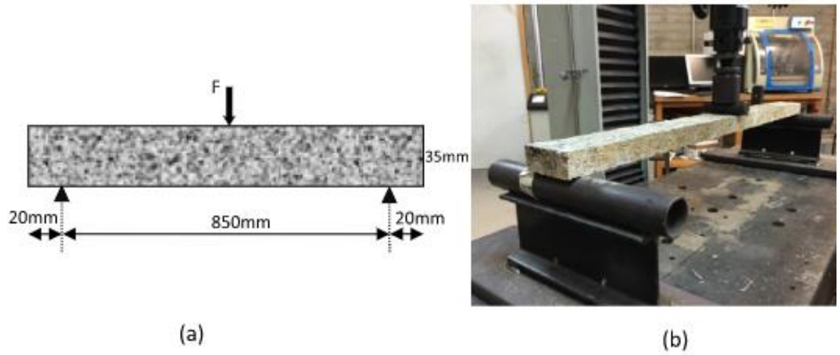

Figure 8 Three-point bending test: (a) geometric and loading characteristics, (b) test setup (Li et al., 2017).

An essential property of concrete used to determine the mechanical strength of a concrete is flexural strength. Due to concrete's use for infrastructure responsible for withstanding large amounts of force, mechanical strength is a large factor in the effectiveness of a concrete. Flexural strength can be assessed using a three-point bending test as depicted in Figure 8. A long beam of concrete is held up by two stationary points at the ends of the panel. In the middle of the beam of concrete, force is applied using an Instron universal testing machine. The greatest amount of force the beam of concrete is able to withstand is recorded. Using this force, bending strength of rupture or flexural strength can be calculated for. Additionally, the data obtained from this test can be used to calculate for the elastic modulus and flexural stiffness.

Conclusion

The water absorption test indicated that the addition of talc increased water absorption, but eventually leveled off as more than 10% talc was added. This water absorption trend was different than in other fine powders, such as blast furnace slag (Deboucha et al., 2015). The compressive strength test revealed that the increase of talc percentage decreased the compressive strength at each level. The compressive strength test was consistent with some other concrete additives, like recycled gravel, but not with other fine powders, such as powdered cellular concrete (Gyurkó et al., 2017). The addition of talc overall increases the water absorption while losing compressive strength. The generally unwanted concrete properties of high water absorption and low compressive strength result in the conclusion that the addition of talc in concrete is ineffective.

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