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Akışkanlaştırıcı Katkı Oranının Betonların Aşınma Direnci Üzerine Etkisinin Araştırılması

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ÖZET

Günümüz teknolojisinde betonun taze veya sertleşmiş özelliklerini şekillendiren çeşitli kimyasal katkı maddeleri bulunmaktadır. İstenilen beton özelliklerini elde etmek için kimyasal katkılar tek başına veya birkaç katkının bir arada kullanılmasıyla eklenebilir. Kullanım dozajları istenilen performans kriterlerini sağlayacak ve aynı zamanda betonun taze ve sertleşmiş özelliklerini bozmayacak şekilde seçilmektedir. Bu çalışmada, en çok kullanılan akışkanlaştırıcı katkı kullanımının betonun fiziksel, mekanik ve aşınma dayanımına etkisi araştırılmaktadır. Bu amaç doğrultusunda, akışkanlaştırıcı katkıyı %0,5, %1, %1,5 ve %2 oranlarında kullanılarak üretilen betonların fiziksel, mekanik ve aşınma dayanımı özellikleri incelenmiştir. Beton numunelerinin üretiminde su/çimento oranı ve çimento miktarı sırasıyla 0,5 ve 350 kg/m^3 olarak sabit tutulmuştur. Agrega olarak 0-4 mm taneli kırma kum ve 4-16 mm tane büyüklüğünde agrega kullanılmaktadır. Kimyasal katkı oranının etkisini görmek amacıyla Arşimet, kılcal su emme, ultrason geçiş hızı, böhme (aşınma), schmidt ve basınç dayanımı testlerine tabi tutulmuştur. Su emme ve gözeneklilik yüzdelerinin en düşük olduğu değerler sırasıyla %3.18 ve %9.32 olarak %1 akışkanlaştırıcı katkı maddesi içeren numunede görülmüştür. Ultrases geçiş hızı, schmidt test çekici ve en yüksek basınç dayanımı değerleri sırasıyla 4901 m/s, 26.1 ve 57.14 MPa olarak %1 akışkanlaştırıcı katkı içeren 28 günlük numunede gözlendi. Kimyasal katkı oranının artması ile aşınmaya bağlı ağırlık kayıpları azalmıştır.

Investigation of the Effect of Plasticizer Additive Ratio on the Abrasion Resistance of Concretes

Research Article

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ABSTRACT

In today's technology, there are various chemical additives that shape the fresh or hardened properties of concrete. Chemical additives can be added alone or by using a combination of several additives to obtain the desired concrete properties. Usage dosages are chosen in a way that will meet the desired performance criteria and at the same time will not impair the fresh and hardened properties of the concrete. In this study, the effect of the most used plasticizer additives on the physical, mechanical and abrasion resistance of concrete is investigated. For this purpose, physical, mechanical and abrasion resistance properties of concretes produced by using plasticizer additive at 0.5%, 1%, 1.5% and 2% ratios were investigated. In the production of concrete samples, the water/cement ratio and cement amount were kept constant as 0.5 and 350 kg/m^3, respectively. As aggregate, crushed sand with 0-4 mm grains and aggregate with 4-16 mm grain size are used. In order to see the effect of chemical additive ratio, archimedes, capillary water absorption, ultrasound transmission rate, böhme (abrasion), schmidt and compressive strength tests were subjected to. The lowest water absorption and porosity percentages were observed in the sample containing 1% plasticizer additive as 3.18% and 9.32%, respectively. Ultrasonic pulse velocity, Schmidt hammer and the highest compressive strength values were observed as 4901 m/s, 26.1 and 57.14 MPa, respectively, in the 28-day-old sample containing 1% plasticizer additive. With the increase in the chemical additive ratio, the weight losses due to abrasion decreased.

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Introduction

Improving the various properties of concrete, providing convenience in production and transportation, etc. the use of chemical additives for these purposes has become quite common in recent years. It is known that various chemical additives are used in cement mortars and concretes both to contribute to the properties of fresh concrete and to increase the strength and durability performance of hardened concrete (Jeknavorian et al., 1998; ASTM C465-19). The functions of chemical additives are classified as normal or highwater reduction, retarding setting, accelerating setting and entraining air (Jeknavorian et al., 1998; Erdoğan et al., 2007). This classification water reducers are used to reduce the w/c ratio or to obtain more workable fresh concrete with a constant w/c ratio and are called plasticizers. Plasticizers are of great importance to the construction industry as the most widely used organic cement additive. The addition of plasticizers in concrete increases the workability of the concrete, reduces the amount of mixing water, changes the rheology of the mixture, and causes delay in setting (Chernyshev et al., 2018).

Adding water to facilitate the placement of fresh concrete adversely affects the concrete performance (Topçu et al., 2006). In order to prevent this effect, it is necessary to easily place the fresh concrete without adding extra water. To achieve this workability in fresh concrete, plasticizer additives are used (Topçu et al., 2006; Stecher et al., 2019). By adding the plasticizer additive to the concrete, agglomeration of the cement particles is prevented or minimized. As the cement particles disperse, the water trapped between them is released and becomes available for workability and cement hydration. However, the surface area of the cement particle exposed to hydration also increases (Jun, 2008). By keeping the w/c ratio constant in the mixing calculation, it is expected that a more fluid and easily placed concrete will be obtained without any loss of strength when different ratios of plasticizer are used (Haruna and Fall, 2020). The fact that good placement and compaction reduces the volume of voids within the concrete is an important factor for the durability of a concrete (Ali and Qureshi, 2019; Sathyan and Anand, 2019). In a concrete where the placement process is facilitated and compression is applied successfully; Improvements are seen in terms of durability due to ensuring a homogeneous mixture, obtaining a smooth surface, and preserving integrity. The fact that the service life of a reinforced concrete structural element is directly related to its durability performance causes researchers to focus on this issue. The fact that the share of maintenance and repair works in construction activities is as high as 40% in developed countries clearly reveals that there are serious problems in terms of durability (Baradan and Aydın, 2013). The reason for the durability problems in the load-bearing structural elements is the various deteriorations in the concrete. Factors that cause deterioration in concrete are mechanical, physical, chemical and biological factors, and the effect of wear is one of the damages caused by mechanical means (Gökçer et al., 2015). Abrasion refers to material losses caused by frictions affecting concrete surfaces, and the surface properties of concrete are of great importance for resistance to abrasion (Naik et al., 2002; Aydın, 2016; Lau et al., 2019; Pranav et al., 2020). Abrasion deterioration in concrete is caused by factors such as gravel, sand and ice slides, wind, and water. Abrasion deterioration causes serious loss of bearing capacity in reinforced concrete structural elements and poses a great threat to important structures. In order to prevent this effect, the abrasion resistance of concrete should be increased.

The aim of this study is to investigate the effect of plasticizer additive ratio on wear resistance. A lot of research has been done on the use of plasticizer additives, which is one of the frequently used chemical additives, but there are not many articles investigating wear resistance. For this purpose, the physical, mechanical and abrasion resistance properties of concretes were investigated by adding plasticizer additives in different ratios into the concrete. In concrete production, the water/cement ratio was kept constant as 0.5, and plasticizer chemical additives were added at 0.5%, 1%, 1.5% and 2% rates. Concrete samples were subjected to slump, water absorption, porosity, ultrasonic, böhme (abrasion), schmidt and compressive strength tests.

Material and Method

Material

CEM I-42,5/R type Portland Cement (PC) produced in accordance with the TS EN 197-1 (2012) standard was used as the binder in the preparation of the samples. The chemical analysis of the cement used was taken from the producer factory, and its physical and chemical properties are given in Table 1.

In the experimental study, potable city mains water of Osmaniye province, which complies with the conditions specified in TS EN 1008 (2003), was used as mixed water. In concrete production, 16 mm was determined as the largest grain size, and 0-4 mm crushed sand and 4-16 mm limestone-based crushed stone with appropriate gradation were used. Surface dry water-saturated densities of fine and coarse aggregates are 2.67 and 2.70 gr/cm^3, respectively. The suitability of crushed sand used in the experiments for use in the experiments was checked in accordance with TS 706 EN 12620+A1 (2009) standards.

Table 1. Chemical and physical analysis of CEM I 42,5 R Portland cement.

Chemical Analysis	(%)
CaO	62.72
SiO_2	20.00
Al_2O_3	4.92
Fe_2O_3	3.76
MgO	1.84
SO_3	2.65
K_2O	0.73
Na_2O	0.26
Loss on Ignition (%)	2.54
Insoluble Residue (%)	-
Physical Properties	
Specific Gravity (g/cm^3)	3.11
Specific Surface (Blaine) (cm^2/g)	3250
Socket Start (min)	145
Socket End (min)	220
Volume Expansion (mm)	1
Compressive Strength (MPa) 28 days	49.5

Chemical additives in accordance with ASTM C494 standard are used in concrete production. The chemical additive used is lignosulfonate-based plasticizer with water reducing effect. The density of the plasticizer additive is 1.12 g/cm^3, the chlorine content is <0.1% and the pH value is 7.23 at 20 °C. It is used at rates of 0.5%, 1%, 1.5% and 2% by weight, depending on the amount of cement. The amount of material required for the preparation of concrete samples is given in Table 2.

Table 2. Amount of material required for 1 m^3 concrete

Sample Name	**Cement (kg)**	**Water (kg)**	**Crushed (kg)**	**Sand**	**Aggregate (kg)**	**Chemical Additive (kg)**
0.5K	350	175	1041		832	1.75
1.0K	350	175	1039		831	3.50
1.5K	350	175	1037		829	5.25
2.0K	350	175	1035		827	7.00

Method

Concrete samples produced with a water/cement ratio of 0.5 and a cement amount of 350 kg/m^3 and containing plasticizer additives at different rates (0.5%, 1%, 1.5%, 2%) are slump, Archimedes, ultrasonic, böhme (abrasion), schmidt and pressure subjected to strength tests.

Slump Test

While producing the concrete samples, the workability of the concretes was checked by applying the slump test. The experiment was carried out by filling a cone-shaped metal mold with standard dimensions with fresh concrete in three layers and skewering each layer 25 times. The amount of slump in the concrete was measured by pulling up the truncated cone filled with fresh concrete (TS EN 12350-2, 2019).

Compressive Strength
In order to determine the compressive strength of concrete samples, cube samples of 150x150x150 mm dimensions were produced. Concrete samples, which completed their setting by waiting in the mold, were removed from the molds at the end of 24 hours and cured for 7 and 28 days, and their compressive strengths were determined. The compressive strengths were applied according to the TS EN 12390-4 (2019) standard with the aid of a 200-ton capacity device.

Böhme (Abrasion) Test
For the friction wear loss test, cube shaped test specimens with 71 mm side lengths were prepared in accordance with TS 2824 EN 1338 (2005). It was subjected to the abrasion test with the bohme device shown in Figure 1. In these samples, the contacting and opposing side should be parallel and flat. In the experiments, 20 g of abrasive powder is sprinkled on the friction strip and loaded with 294 N by means of a steel lever. After 22 cycles, sanding dust and sample wastes are cleaned from the disc that stops automatically. Again, 20 gr of abrasive powder is sprinkled on the friction strip and the sample is rotated 90º around the vertical axis. The test, consisting of 22 cycles for each sample, is applied to the sample 16 times. After the test sample is thoroughly cleaned, the sample is weighed on a precision balance and the weight loss is noted.

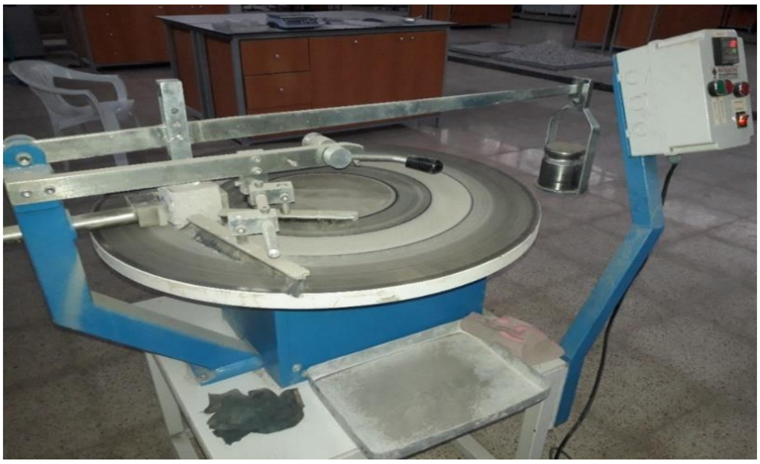

Figure 1. Böhme experimental setup

Water Absorption and Porosity
The porosity and water absorption properties of all samples were determined in accordance with the TS EN 1170-6 (1999) standard with the aid of scales working with the Archimedean principle. The samples were removed from the curing pool at the end of 28 days, and their weight in the water was recorded by placing them in the wire basket on the specific gravity stand. The surfaces of the samples removed from the water were dried using a cloth and the dry surface saturation weights were taken. The samples were dried for 24 hours in an oven operated at 105 ºC and turned into an oven dry. The temperature of the samples taken out of the drying oven was expected to decrease to room temperature and then the oven dry weights were weighed.

Ultrasonic Pulse Velocity

Ultrasonic Pulse Velocities of the samples were calculated using an Ultrasonic tester (P-wave). The TS EN 12504-4 (2021) standard is based on the Ultrasonic Pulse Velocity test applied in the oven-dry state. The distance between the two surfaces of the samples was measured with the help of a caliper and processed on the device, and ultrasonic gel was used to prevent air gaps on the surfaces to be measured. The sample was placed between the probes (transmitter-receiver) and aligned, and the device was operated. The transit time of the sound wave in the device is recorded. With the help of the distance in the measurement direction and the sound transmission time measured by the device, the necessary calculations were made, and the Ultrasonic Pulse Velocities were calculated and noted.

Figure 2. Ultrasonic transmission rate determination

Schmidt Test Hammer

Schmidt hammer test was carried out on concrete samples with dimensions of 100x100x100 mm. 12 readings were taken from each sample, and attention was paid to ensure that there was a minimum of 20 mm between each reading point and 40-50 mm space was left from the edges. After making 12 readings, the arithmetic average of the remaining 10 readings was taken, ignoring the largest and smallest values. In this way, an average R value representing the test surface was obtained. In the implementation of the experiment, the TS EN 12504-2 (2021) standard was used.

Results and Discussion

Slump Test

During the production of concrete samples, the data of the slump test applied to the fresh concrete mixtures are given in Figure 3. It is seen that the amount of slump obtained from concrete samples increases as the use of plasticizer additives increases. The highest slump value was observed in the concrete with 15.5 cm and 2% plasticizer admixture. Consistent with the data obtained, Benaicha et al. (2019) showed in their study that the workability of fresh concrete improves as the amount of plasticizer used increases.

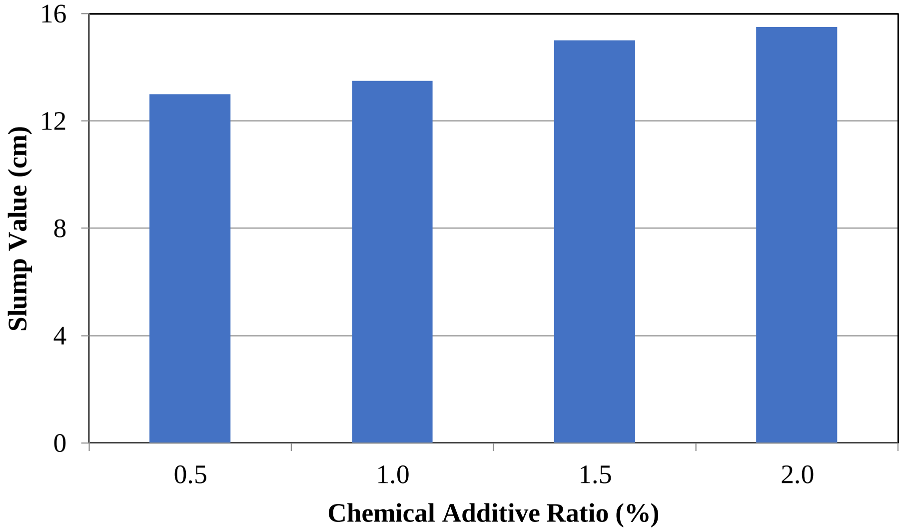

Figure 3. Slump values of concrete samples

Compressive Strength

The 7- and 28-day compressive strength values of the samples are given in Figure 4. According to the test results of the 7-day samples, the highest compressive strength value was 50.7 MPa in the sample with 1% plasticizer additive, while the lowest compressive strength value was 47.72 MPa in the sample with 2% plasticizer additive added. According to the test results of the 28-day samples, while the highest compressive strength value was 57.14 MPa in the sample with 1% plasticizer additive, the lowest compressive strength value was observed in the sample with 2% plasticizer additive as 53.41 MPa. The 1% plasticizer admixture used in the concrete sample caused the concrete sample to mix more homogeneously and settle better than the other samples, thus minimizing the porous structure and thus achieving higher strength without reducing the water/cement ratio. Consistent with these findings, Klein and Simon (2006) observed in their study that the use of plasticizers at recommended rates has a positive effect on the short and long-term compressive strength of concretes. While it was observed that the ideal plasticizer use was 1% in terms of compressive strength, it was observed that the consistency could be significantly improved by experiencing negligible strength drops as a result of using higher rates (1.5% and 2%).

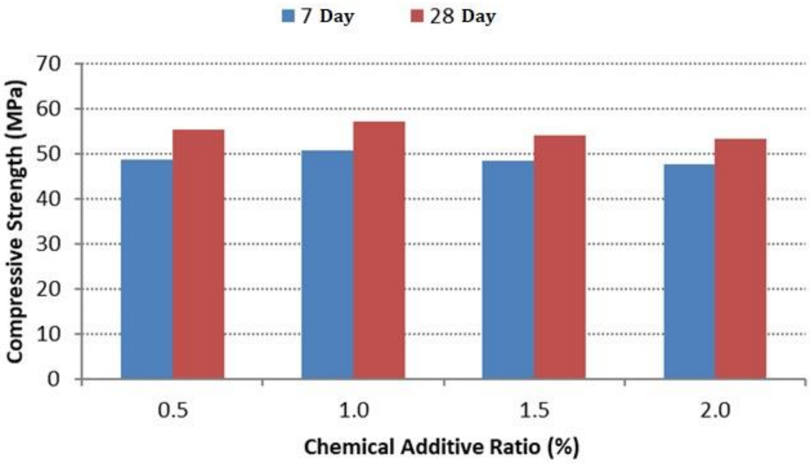

Figure 4. Compressive strength values of concrete samples

Böhme (Abrasion) Test

The weight loss percentages of the concrete samples calculated after the abrasion test are given in Figure 5. When the plasticizer additive is used at 0.5%, 1%, 1.5% and 2% ratios, it is seen that the weight loss percentages are 5.45%, 5.19%, 3.99% and 3.55%, respectively. It has been observed that the surface properties of concrete have a significant effect on its performance under the influence of wear. Although the use of plasticizer ratio more than 1% increased the void ratio in the internal structure, it resulted in obtaining samples with extremely smooth surfaces. With the increase of plasticizer addition, obtaining smoother surfaces in the samples increased the surface strength of the concrete samples. This resulted in a reduction in surface wear, resulting in a reduction in weight losses due to wear. There are studies in the literature that argue and reveal that wear resistance is affected by surface properties rather than the strength of concrete (Silva et al., 2019). When the data were examined, it was observed that the weight loss seen in the concrete sample produced with the addition of 2% plasticizer additive was 34.86% lower than the weight loss observed in the concrete sample produced with the addition of 0.5% plasticizer additive.

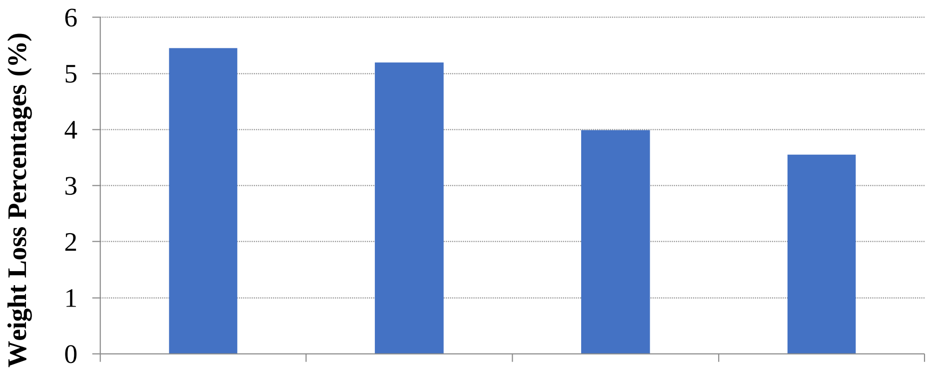

Figure 5. Böhm weight loss values of concrete samples

Water Absorption and Porosity

Water absorption and porosity percentages of concrete samples are given in Figure 6 and 7. According to the Archimedean test results, it is seen that the lowest water absorption percentage value is read as 3.18% in the sample containing 1% plasticizer additive. The highest water absorption percentage was read as 3.29% in the sample containing 2% additive. In porosity values, similar to the results in water absorption percentages; while the lowest value was observed as 9.32% in the sample containing 1% plasticizer additive, the highest value was observed as 9.58% in the sample containing 2% plasticizer additive. It is seen that while the void ratio and water absorption values decrease with 1% plasticizer additives, they increase with the use of 1.5% and 2% additives. The lowest water absorption and porosity observed in the sample containing 1% plasticizer additive indicates that the best settlement is achieved in the concrete using 1% plasticizer additive and the voids in the internal structure remain at a minimum level.

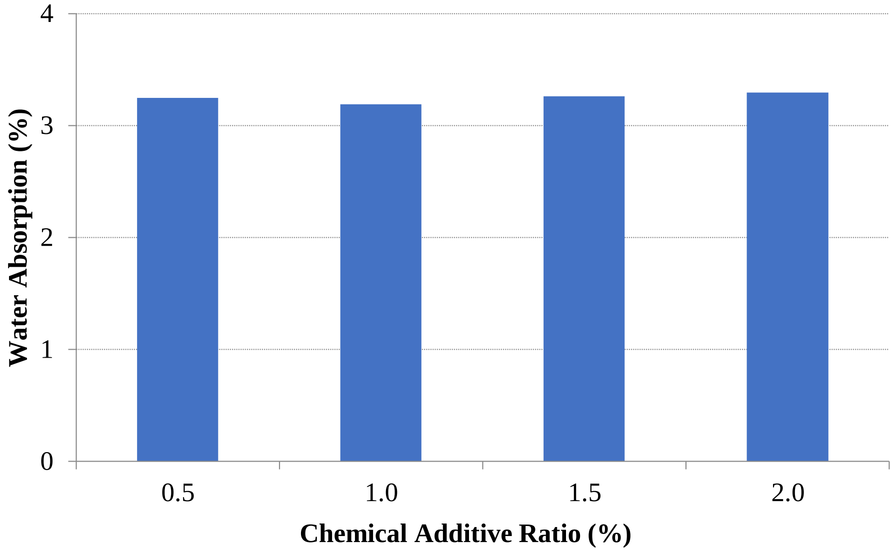

Figure 6. Water absorption percentages of concrete samples

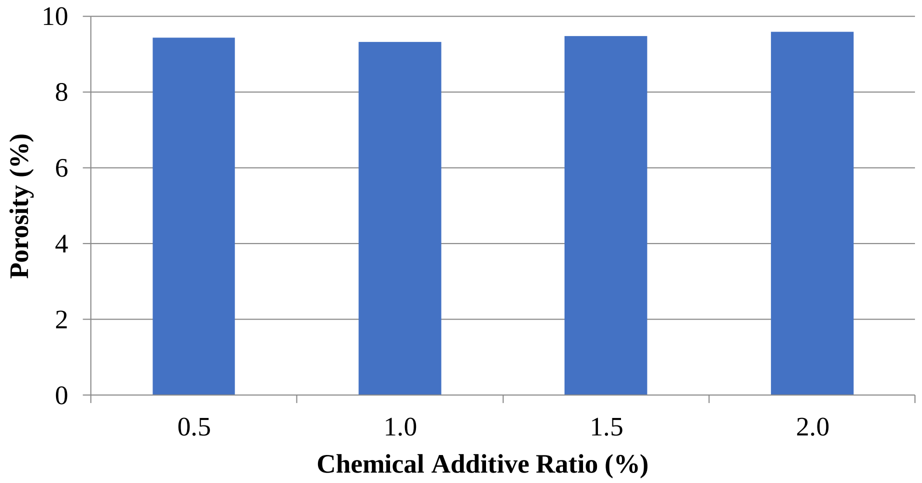

Figure 7. Porosity percentages of concrete samples

Ultrasonic Pulse Velocity

Ultrasonic Pulse Velocity of concrete samples is given in Figure 8. The highest transition velocity was measured as 4901 m/sec in concrete samples with 1% plasticizer additive. The lowest Ultrasonic Pulse Velocity was measured as 4672 m/sec in concretes with 2% plasticizer additive added. The Ultrasonic Pulse Velocity increases or decreases in relation to the void amount of the object and gives an idea about the strength of the concrete. While it is seen that the ultrasonic Pulse Velocity takes low values in the samples with void structure, high results are obtained in the samples with few voids. Many studies in the literature indicate that Ultrasonic Pulse Velocities decrease with an increase in the void ratio (Mendes et al., 2020). The fact that the highest ultrasonic transmission velocity was measured as 4901 m/s in the concrete sample containing 1% plasticizer additive supports that the porous structure remains at a minimum level in this sample. All concrete is classified as high-quality concrete as it is higher than 4000 m/s.

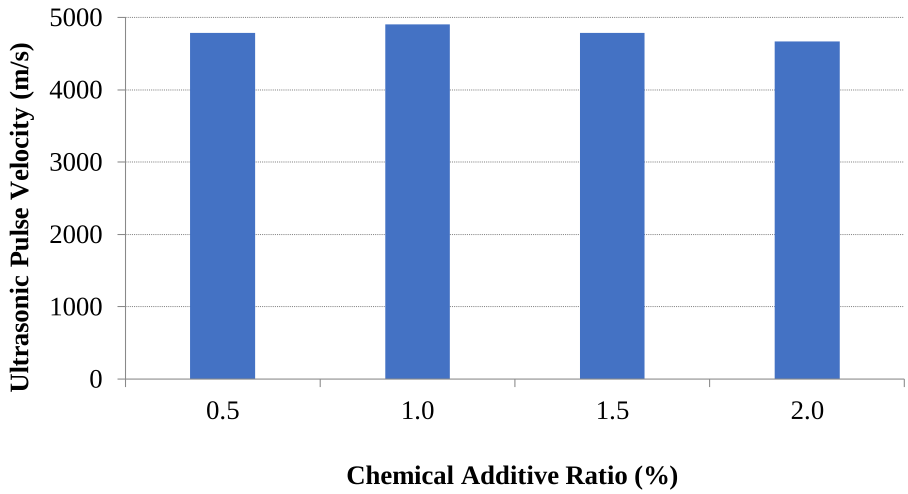

Figure 8. Ultrasonic pulse values of the samples

Schmidt Test Hammer

Schmidt test hammer readings of concrete samples are given in Figure 9. The highest value was read as 27.2 in the sample containing 2% chemical additive. The lowest value was read as 24.2 in the sample containing 0.5% chemical additive. Like the Ultrasonic Pulse Velocity, the data from the Schmidt test hammer readings also give an idea about the mechanical property of the concrete. Schmidt rebound value expresses the surface hardness, which has an effective role on the abrasion resistance of concretes. Considering the results obtained from the concrete samples, it is seen that the Schmidt rebound values are also high in the samples with lower weight losses due to abrasion. Topsakal and Özel (2012) stated in their study that there is a relationship between surface hardness and slump value. The data obtained showed that increasing the workability with the use of plasticizer additives can increase the surface hardness of the concrete.

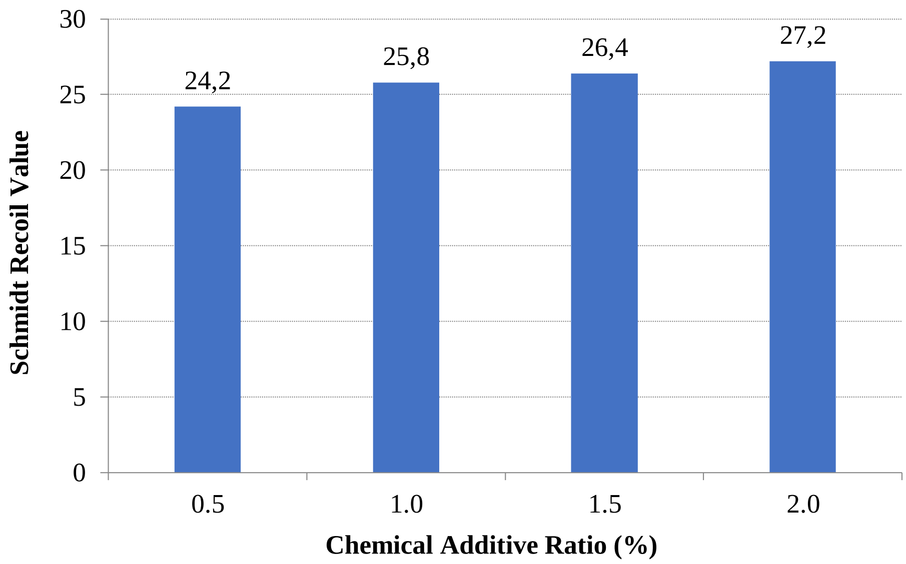

Figure 9. Schmidt hammer readings of samples

Conclusion and Recommendations

- As seen in the results of ultrasonic transmission velocity and compressive strength tests, the use of 1% plasticizer admixture enabled the concrete to achieve the best performance in terms of mechanical and physical properties. Considering this situation, the ideal plasticizer usage rate for the permeability and strength properties of concrete can be evaluated as 1%.
- In our study, besides the mechanical and physical properties, the wear deterioration, which is a durability problem, was also examined and it was determined that the use of plasticizer additives greatly improved the resistance of concrete against abrasion.
- According to the Archimedean test results, it is seen that the lowest water absorption percentage value is read as 3.18% in the sample containing 1% plasticizer additive. The highest water absorption percentage was read as 3.29% in the sample containing 2% additive.
- In porosity values, similar to the results in water absorption percentages; While the lowest value was observed as 9.32% in the sample containing 1% plasticizer additive, the highest value was observed as 9.58% in the sample containing 2% plasticizer additive.
- It is seen that while the void ratio and water absorption values decrease with 1% plasticizer additives, they increase with the use of 1.5% and 2% additives. The lowest water absorption and porosity observed in the sample containing 1% plasticizer additive indicates that the best settlement is achieved in the concrete using 1% plasticizer additive and the voids in the internal structure remain at a minimum level.
- The highest transition velocity was measured as 4901 m/sec in concrete samples with 1% plasticizer additive. The lowest ultrasonic pulse velocity was measured as 4672 m/sec in concretes with 2% plasticizer additives. The highest ultrasonic pulse velocity was measured as

4901 m/sec in the concrete sample containing 1% plasticizer additive, which also supports that the porous structure remained at a minimum level in this sample.

- When the plasticizer additive is used at 0.5%, 1%, 1.5% and 2% ratios, it is seen that the weight loss percentages are 5.45%, 5.19%, 3.99% and 3.55%, respectively. It has been observed that the surface properties of concrete have a significant effect on its performance under the influence of wear. Using more than 1% plasticizer ratio increased the void ratio in the internal structure but resulted in samples with extremely smooth surfaces.
- The obtaining of smoother surfaces in the samples with the increase of the plasticizer addition caused a decrease in the surface abrasions, resulting in a decrease in the weight losses due to abrasion.
- According to the compressive strength test results of 7-day samples, the highest value was seen as 50.7 MPa in the sample with 1% plasticizer additive.
- The results obtained as a result of the study; It has been shown that the workability properties are improved without a significant decrease in compressive strength values with the use of plasticizer additives, so that the concretes that are placed more easily have smooth surfaces and high surface strengths and become more resistant to abrasion.

Conflict of Interest Statement

The article author declares that there is no conflict of interest.

Contribution Rate Statement Summary of Researchers

The contribution of the authors is equal.

*This study was presented as a summary paper at the International Conference on Engineering, Natural and Applied Sciences (ICENAS'21) held online on 24-26 November 2021.

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