Avrupa Bilim ve Teknoloji Dergisi
Sayı 17, S. 901-908, Aralık 2019

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 17, pp. 901-908, December 2019

Research Article

Kimyasal Katkılı Betonların Dayanım Özelliklerine Dayalı Bir Çalışma

Esra Tuğrul Tunç[1*]

[1] Fırat Üniversitesi, Mühendislik Fakültesi, İnşaar Mühendisliği Bölümü, Elazığ, Türkiye (ORCID: 0000-0001-9071-774X)

(İlk Geliş Tarihi 11 Kasım 2019 ve Kabul Tarihi 7 Aralık 2019)

(**DOI:** 10.31590/ejosat.649737)

REFERENCE: Tuğrul Tunç, E. (2019). Kimyasal Katkılı Betonların Dayanım Özelliklerine Dayalı Bir Çalışma. *Avrupa Bilim ve Teknoloji Dergisi*, (17), 901-908.

Öz

Günümüzde beton sektöründe kimyasal katkı kullanımı oldukça yaygınlaşmıştır. Kimyasal katkı kullanımı ile beton performansının daha da iyileştirilmesi mümkündür. Kimyasal katkı oranı arttıkça her zaman beton dayanımı artmaz. Üretici firmaların farklı katkı tipleri için önerdikleri optimum kullanım dozajlarına dikkat edilmesi gerekmektedir. Kimyasal katkıların beton durabilitesine olumlu etkisinin yanı sıra işlenebilirliği ve sıkıştırılmasında da fayda sağlamaktadır. Ayrıca, beton geçirgenliğini azaltma ve donma-çözülme dayanımını arttırma gibi avantajları da mevcuttur. Bu çalışmada beton üretiminde yüksek oranda su azaltıcı (süper akışkanlaştırıcı) kimyasal katkı kullanılmıştır. Bunun nedeni; bu katkının kıvamı değiştirmeden su miktarını yüksek oranda azaltarak çökme ve yayılmayı yüksek oranda arttırma etkisi oluşturmasıdır. Bu çalışmada üretici firmanın önerdiği oranda söz konusu kimyasal katkı kullanılarak bir dizi beton numunesi hazırlanmıştır. Karışım dizaynı belirlenmiş bu numuneler, kürden sonra beton basınç dayanım testine tabi tutulmuştur. Kimyasal katkının basınç dayanımına etkisini belirleyebilmek için bir dizi de katkı içermeyen referans numunesi dökülmüştür. Böylece katkılı ve katkısız beton numunelerin basınç dayanımları karşılaştırılarak tartışılmıştır. Sonuç olarak, istenen özellikte beton üretmek için uygun katkı tipi ve oranında kimyasal katkı kullanımı ile beton dayanımının iyileştiği belirlenmiştir.

Anahtar Kelimeler: Kimyasal Katkı, Mermer Beton, Dayanım Testleri, Referans Numuneler.

An Experimental Study Based on the Strength Properties of Concrete Containing Chemical Admixture

Abstract

Today, the use of chemical admixtures has become widespread in the concrete sector. It is possible to further improve the performance of concrete with the use of chemical admixtures. As the chemical admixture ratio increases, the concrete strength does not always increase. It is necessary to pay attention to the optimum contents recommended by the manufacturers for different types of admixtures. As well as the positive effect of chemical admixtures on concrete durability, it also provides benefits in workability and compaction. It also has the advantages of reducing the concrete permeability and increasing the freeze-thaw stability. In this study, a high water reducing superplasticizer as chemical admixture was used in concrete production. This is because; this admixture has the increasing the slump and spreading of concrete at a high ratio without changing the concrete consistency. In this study, a series of concrete specimens were prepared by using the chemical admixture at a certain ratio. These specimens were conducted to concrete compressive and splitting tensile strength tests. In order to determine the effect of the chemical admixture on the concrete strength, a series of reference specimens without admixtures were prepared. Thus, the strength of concrete specimens with admixture and non-admixture were compared and discussed. As a result, it has been determined that the strength of the concrete is improved by the use of chemical admixture at a certain ratio and type of admixture to produce the concrete with the desired properties.

Keywords: Chemical admixture, Marble concrete, Strength tests, Reference specimens.

[1] Sorumlu Yazar: Fırat Üniversitesi, Mühendislik Fakültesi, İnşaar Mühendisliği Bölümü, Elazığ, Türkiye (ORCID: 0000-0001-9071-774X, esratugrul@firat.edu.tr

1. Introduction

Concrete is the most common building material used in many different structures in the construction sector. Since the low cost and easy production of concrete, it is widely used in buildings, roads, bridges, dams, power plants, retaining walls, airports, urban furniture, etc. It is seen to have widespread use in many applications (Topçu et al., 2006). Due to concrete's intensive use, it is observed that the raw material resources such as cement, aggregate and water that form the concrete gradually decrease. Therefore, energy conservation and harmful flue gas emissions must be restricted. Thus, it is recommended to use mineral and chemical admixtures, industrial wastes and alternative materials in concrete production (Tunc, 2019).

Granular building materials such as sand, gravel and crushed stone used in concrete production are called aggregates. Aggregates account for approximately 70% of the total volume of concrete (Tunc and Alyamac, 2019). Therefore, chemical composition, mineralogical structure, petrographic structure and physical properties of aggregates used in concrete production should be investigated well. It is known that all these properties significantly affect the performance, quality, strength and durability of concrete (Taşdemir, 2001).

Advances in technology and science have made chemical admixtures the proposed component of concrete. In today's modern concrete technology, it is almost impossible to produce a high-strength concrete without chemical and mineral admixtures (Felekoğlu et al., 2004). Concrete admixtures are used to improve the performance of concrete by changing some properties of concrete and to make the concrete more economical. Chemical admixtures are used in the production of concrete for increasing the workability of fresh concrete, improving the setting times and increasing the strength and durability of hardened concrete (ACI 212.3R-10, 2010 and Pekmezci et al., 2014). The suitability of the admixtures to be used in concrete should be determined by experiments. A poorly designed concrete mixture cannot be improved by using chemical admixtures, but the performance of a quality concrete can be further improved.

Since the amount of admixture is very small among the other components of the concrete, it can sometimes lead to a major problem in practice to add more amounts of admixture than is proposed during concrete production. In such cases, the slump value of the concrete increases excessively and the concrete loses its stability and can decompose. The effect of the chemical admixture is not directly proportional to increasing the content of the admixture. For this reason, the optimum contents recommended by the manufacturers for the types of admixtures should be considered (Sağlam and Akman, 2002).

The aim of this study is to determine and compare the properties of fresh and hardened concrete for the concretes with chemical admixture and for reference concrete. For this purpose; using marble aggregates of different sizes, reference concrete specimens and concrete specimens with chemical admixture were prepared for 3 different water cement ratios for constant cement content. The fresh concrete properties of the produced concrete specimens were determined by using a slump funnel. Slump values of the concretes containing chemical admixture were compared with slump values of the reference concretes. Then, a series of 150×150×150 mm concrete specimens were produced for both mixtures. In order to determine the hardened concrete properties of concrete specimens, the specimens were subjected to 28 day compressive strength and splitting tensile strength tests. The results obtained from the related experiments were compared. In addition, the relationship between compressive strength and splitting tensile strength of the concrete specimens was determined. As a result, it has been seen that the performance of concrete improves with the use of chemical admixtures in correct and appropriate ratio.

2. Use of Chemical Admixtures in Concrete Produciton

In addition to cement, aggregate, water and mineral admixtures, which are the basic materials forming concrete, chemical admixtures are added to the concrete. According to ASTM C125-12, chemical admixtures can be added to the concrete during the concrete production stage, except the water, aggregate, cement and fiber reinforcement materials that form the main components of concrete or mortar. According to TS EN 206, chemical admixtures is added to the concrete in small amounts compared to the cement mass during the mixing process in order to improve properties of fresh and hardened concrete. In TS EN 934-2, many types of admixtures are defined as water reducing admixture, high water reducing admixture, water retaining admixture, air entraining admixture, setting accelerator admixture, setting retarding admixture, water impermeability admixture, plasticizer admixture and superplasticizer admixtures. Superplasticizers are a chemical admixture which reduces the amount of water in the concrete. Super plasticizers enable the properties of the fresh concrete to reach the desired values such as slump and spreading, while at the same time shortening the curing time and increasing the workability at a high rate. Thanks to superplasticizers, concrete with very low water cement ratio can now be produced and consequently it is possible to produce concrete with high strength and durability to environmental effects (TS EN 480-10).

The use of superplasticizers in concrete is very common. These admixtures have been an indispensable component of concrete since the 1960s. Plasticizers have been used to achieve higher strength by reducing the water cement ratio, to reduce the hydration heat of concrete and to reduce the amount of cement to provide easy settlement (Akman, 1987; Yıldırım, 1996). Plasticizers are organic substances that dissolve in water and reduce the surface tension of the water and prevent air agglomeration by dragging air into the concrete (Topçu, 1996). Yazıcı (2003) observed that superplasticizer admixture improves the workability, while the mixing water decreases and the compressive strength increases with the admixture. In Erdoğdu (2005)'s study, a sulphonated naphthalene based superplasticizer was used to examine the slump loss of silica fume-substituted concretes, and the slump loss after half an hour was reported to be around 55%. In Alsadey (2012), it is stated that the slump loss of concrete containing a melamine based superplasticizer is around 40%.

The main advantages of superplasticizer admixtures; to increase the workability of the concrete by placing the concrete easily without causing a decrease in the amount of cement and strength, to produce high-strength concrete with normal workability but using less amount of water, to be processed with low cement and to produce concrete of normal strength. Because of these properties, a high water reducing superplasticizer admixture was used in the present experimental study.

3. Experimentation

In this experimental study, a mixture aggregate with the largest grain size of 31.5 mm was used by using marble aggregates of different sizes. Saturated surface dry specific weights and water absorption values of the aggregates are given in Table 1. These values are in compliance with the relevant standard TS EN 1097-6. As a result of the grain size analysis tests performed in the laboratory, the grain size curve of the mixture aggregate used in the present study is appropriate according to TS802. Maximum compactness is provided by the curve graph of the mixture falling between A_{32}-B_{32} standard curves.

Table 1. *Specific gravity and water absorption values of the marble aggregates*

Sizes of marble aggregates	Specific gravity (g/cm^3)	Water absorption (%)	Mixing ratios (%)
Coarse	2.40	0.9	25
Medium	2.68	1.2	25
Fine	2.72	1.7	50

In the experiments, CEM I 42.5 N Portland cement conform to relevant standard (TS EN 197-1) obtained from cement factory having specific weight of 3.17 g/cm^3 was used. Initial setting time of this cement is 2.7 h and final setting time is 3.8 h. The Blaine specific surface area is 3520 cm^2/g. According to TS EN 197-1; the compressive strengths of cement mortar for 2 days, 7 days and 28 days are given as 26.8 MPa, 39.1 MPa and 48.6 MPa respectively. Table 2 shows the properties of the high water reducing superplasticizer admixture used in the experimental study.

Table 2. *The physical properties of the superplasticizer admixture*

Appearance	*Liquid*
Color	*Brown*
Density (gr/cm^3)	1.075 ± 0.02
pH	4.00 ± 1
Chloride content	< % 0.1
Recommended usage ratio (%)	0.5 – 1.5

In the present experimental study, the effect of chemical admixtures on the fresh and hardened concrete properties of the produced concrete specimens was investigated. In all mixtures, total binder (cement) was kept constant as 400 kg/m^3. A series of concrete specimens were prepared with and without chemical admixture with water cement ratios of 0.38, 0.40 and 0.42 with the aggregates of different sizes. In the production of concrete containing chemical admixture, superplasticizers were used at 1.2 % of cement weight in the ratios recommended by the manufacturer. Table 3 shows the aggregates, cement and water weights (for 1 m3) of different sizes for prepare concrete mixtures containing the marble aggregates. In Table 3, concrete specimens containing the admixture are named AMC and reference concrete specimens are called RMC. The concrete specimens were prepared considering the saturated surface dry weight of the aggregates.

Table 3. *Mix design of concrete mixture and slump values*

	RMC – AMC		
	RMC1 – AMC1	RMC2 – AMC2	RMC3 – AMC3
Cement (kg/m^3)	400	400	400
Coarse (kg/m^3)	465.8	460.5	455.2
Medium (kg/m^3)	468.1	462.8	457.2
Fine (kg/m^3)	890.7	880.6	870.5
w/c (-)	0.38	0.40	0.42
Slump (cm)	0 - 3	2 - 6	3.5 – 8.0

AMC and RMC concrete mixtures were prepared by using a mixer which can rotate around 1.5 axis/second with its vertical axis with its mixture design given in Table 3. Slump test was performed to determine the fresh concrete properties of AMC and RMC mixtures (Figure 1). For this purpose, truncated funnel in accordance with TS EN 12350-2 standard was used. As shown in Figure 1, the slump values of AMC mixtures (using superplasticizer admixture) showed an increase compared to reference concrete. The slump values of the RMC mixtures ranged from 0 to 3.5 cm, while the slump values of the MC mixtures ranged from 3.0 to 8.0 cm.

(a) (b)

Figure 1. *The determination of the slump values of the concrete mixtures: a) RMC, b) AMC.*

42 concrete specimens of 150×150×150 mm were produced to determine the hardened concrete properties of AMC and RMC concrete mixtures. The respective concrete specimens were placed in a curing pool at a temperature of 23 ± 2 °C and subjected to a 28-day. Cured specimens were subjected to strength tests to determine the hardened concrete properties. In this context, compressive strength test for 12 concrete cube specimens of 150×150×150 mm according to TS EN 12390-3 standard for AMC concretes. The application of compressive strength test was shown in Figure 2a. Splitting tensile strength tests were conducted in accordance with TS EN 12390-6 standard for 9 cube specimens of the same size. The application of splitting tensile strength test was shown in Figure 2b. The same experiments were repeated for RMC specimens (i.e. 12 compressive strength tests and 9 splitting tensile strength tests). The appearance of the specimens after the experiments are given in Figure 2c.

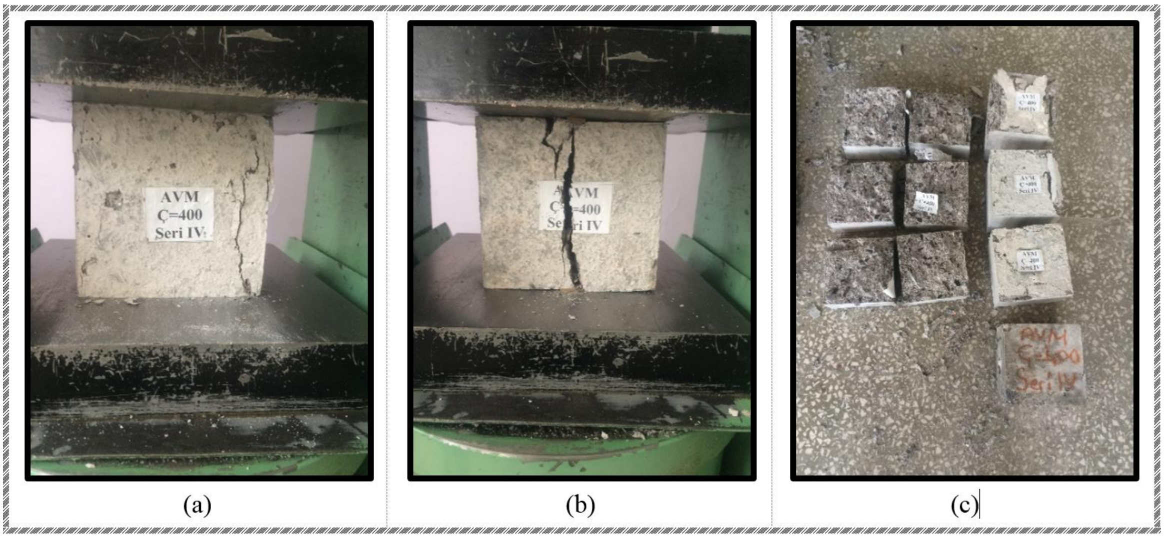

Figure 2. *(a) Compressive strength test; (b) Splitting tensile strength test; c) Appearance of specimens after the experiments*

4. Analysis of Experimental Results

Within the scope of the present study, the effects of chemical admixture on fresh and hardened concrete properties were investigated by considering related admixture. The use of a highly water reducing superplasticizer admixture to achieve high strength from concrete appears to be appropriate by the literature (Tunç et al., 2018). In this study, a series of reference marble concrete (RMC) were prepared with a certain mixture design (Table 3). In addition, a series of marble concrete with chemical admixture (AMC) were prepared using almost the same mixture design (Table 3) with the recommended ratio of superplasticizer admixture (1.2%). In general, it has been concluded that the fresh and hardened concrete properties improved by using chemical admixture.

Figure 3 shows that the slump values of all AMC specimens are higher than the slump values of RMC specimens. The slump values of the AMC specimens appear to be sufficient to obtain a concrete suitable for use. It can be said that AMC specimens can be settlement more conveniently than RMC specimens.

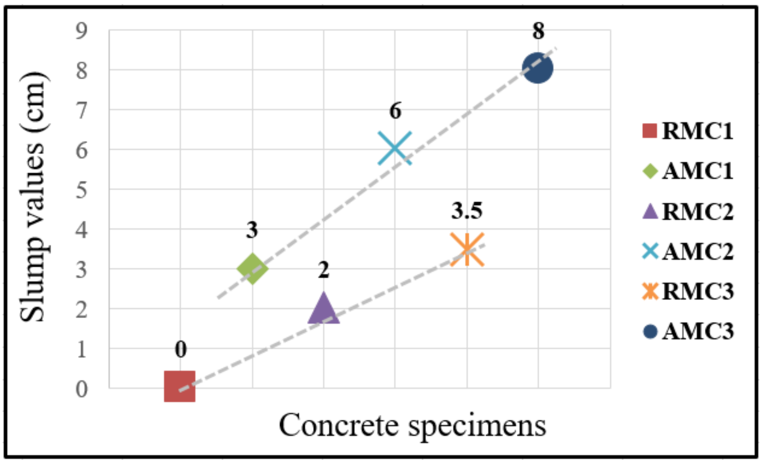

Figure 3. *Slump values of the concrete specimens*

The concrete specimens were prepared for 3 different water cement ratios (0.38, 0.40, 0.42). It seen that compressive strength of the all specimens decreases with increasing water cement ratio (Figure 4). This result is consistent with the literature (Tunç, 2018). The decreases in compressive strength of RMC specimens were found to be higher than AMC specimens. For RMC specimens, it was obtained that 6% decrease in compressive strength with increasing *w*/*c*=from 0.38 to 0.40 and 16% decrease in compressive strength with increasing *w*/*c*=from 0.40 to 0.42. For AMC specimens, it was obtained that 3.5% decrease in compressive strength with increasing *w*/*c*=from 0.38 to 0.40 and 10% decrease in compressive strength with increasing *w*/*c*=from 0.40 to 0.42. It was determined that there was an average of 9.2% difference between the compressive strengths of RMC and AMC specimens for *w*/*c*=0.38, about 11.7% difference for *w*/*c*=0.40, and about 17.3% difference for *w*/*c*=0.42. As can be seen, it is concluded that the chemical additive significantly improves the compressive strength of the concrete specimens.

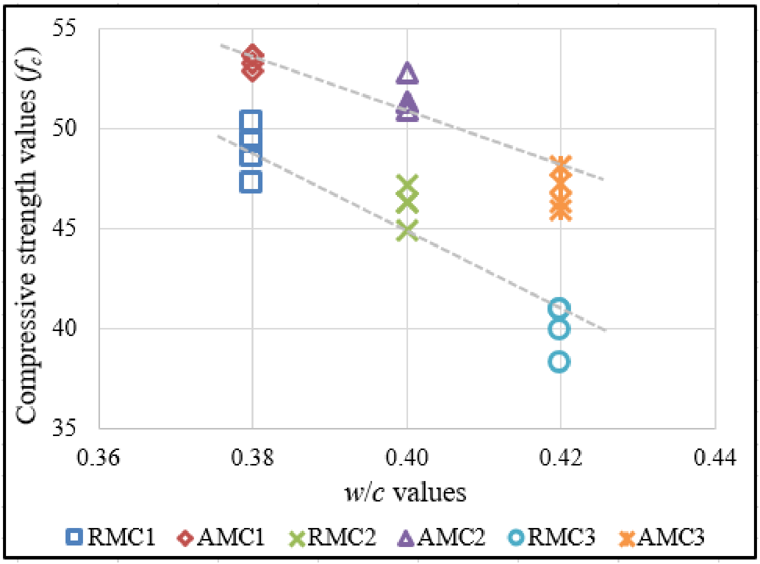

Figure 4. *Variation of compressive strength with w/c values for RMC and AMC specimens*

It is presented the splitting tensile strength test results (another hardened concrete property) in Figure 5. Accordingly, it is seen that there is a tendency to decrease in compliance with the compressive strengths. It is seen that RMC and AMC specimens have very similar decreasing tendencies for splitting tensile strength values. It was determined that splitting tensile strength of all specimens decreased with increasing water cement ratio. For RMC specimens, it was obtained that 7% decrease in splitting tensile strength with increasing *w*/*c*=from 0.38 to 0.40 and 11% decrease in splitting tensile strength with increasing *w*/*c*=from 0.40 to 0.42. For AMC specimens, it was obtained that 9% decrease in splitting tensile strength with increasing w/c=from 0.38 to 0.40 and 7.5% decrease in splitting tensile strength with increasing *w*/*c*=from 0.40 to 0.42. It was determined that there was an average of 6.8% difference between the splitting tensile strengths of RMC and AMC specimens for *w*/*c*=0.38, about 4.9% difference for *w*/*c*=0.40, and about 8.2% difference for *w*/*c*=0.42. It was determined that the highest increase in compressive strength and splitting tensile strength of concrete specimens was observed for *w*/*c*=0.42. As can be seen, it is concluded that the chemical additive significantly improves the splitting tensile strength of the concrete specimens.

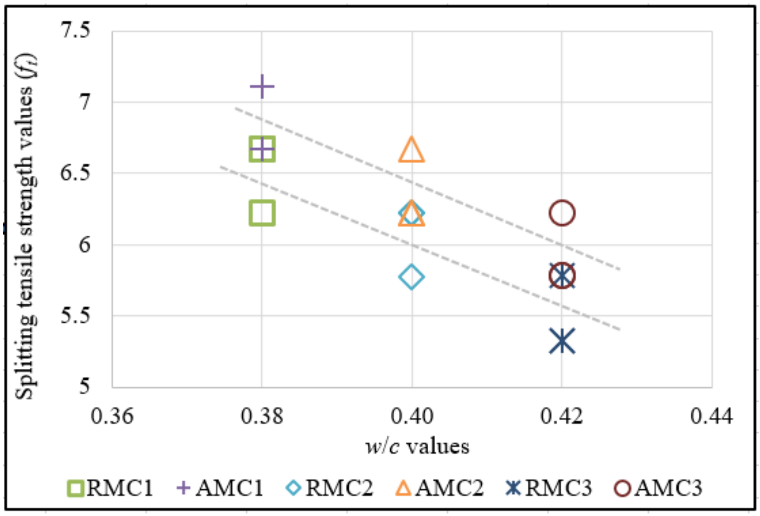

Figure 5. *Variation of splitting tensile strength with w/c values for RMC and AMC specimens*

A good correlation was found between the mean compressive strength values and the mean splitting tensile strength values. Since the correlation coefficient is R^2=0.88, this interpretation can be made with confidence. As compressive strength and splitting tensile strength are the most important hardened properties of concrete. These values change in direct proportion with each other in Figure 6.

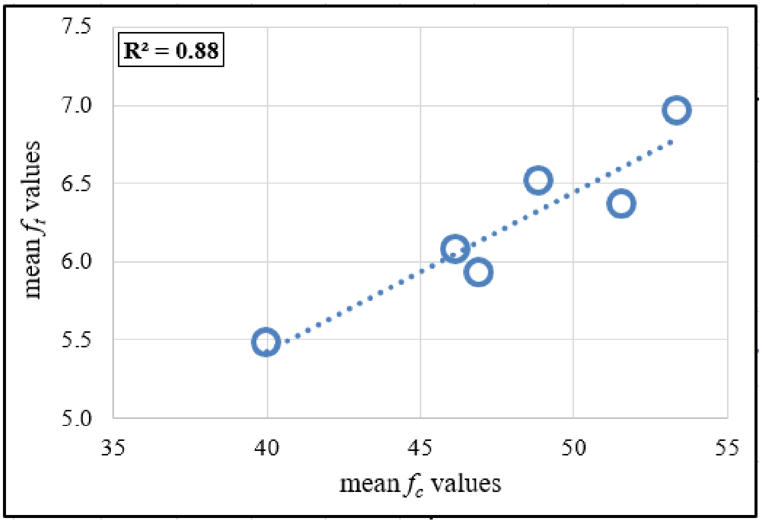

Figure 6. *Relationship between mean compressive strength values and mean splitting tensile strength values*

5. Conclusions

The conclusions obtained from this experimental study, which investigated the effect of appropriate chemical admixture on the properties of fresh and hardened concrete by using it appropriately in concrete, are given below.

- If high strength is required in concrete, it is appropriate to use a high water reducing superplasticizer admixture as a chemical admixture.
- As the water cement ratio increases, the strength of the concrete containing chemical admixture (AMC) decreases less than the reference concrete (RMC).
- The slump values of concrete, which is the characteristic of fresh concrete, give a direct idea about concrete strength.
- It is seen that the fresh and hardened concrete properties of the RMC specimens are significantly improve.
- It has been concluded that it is possible to produce high-strength concrete by using suitable chemical additives according to the purpose of use.
- It was observed a very good correlation between compressive strength and splitting tensile strength values.

6. References

ACI 212.3R-10, 2010. "Report on Chemical Admixtures for Concrete", American Concrete Institute, 65p.
Akman, M. S. (1987). Beton Katkı Maddelerinin Ana İşlevleri ve Yan Etkileri. İTÜ. İnşaat Fakültesi, Malzeme Seminerleri, İstanbul.
Alsadey, S. (2012). Influence of superplasticizer on strength of concrete. International Journal of Research in Engineering and Technology, 1(3), 164-166.
ASTM C125-12, 2012. Standard terminology relating to concrete and concrete aggregates. ASTM International.
Erdoğdu, Ş. (2005). Effect of retempering with superplasticizer admixtures on slump loss and compressive strength of concrete subjected to prolonged mixing. Cement and Concrete Research, 35(5), 907-912. https://doi.org/10.1016/j.cemconres.2004.08.020
Felekoğlu, B., Türkel, S. and Baradan, B. (2004). Kendiliğinden yerleşen beton: Bölüm-1 genel tanıtım, kullanım alanları. TMMOB, İnşaat Mühendisleri Odası İzmir Şubesi, Haber Bülteni, 5, 20-24.
Pekmezci, B. Y. and Atahan, H. N. (2014). Kimyasal ve nano katkılar: betonda kullanımı ve beton performansına etkileri. Hazır Beton Dergisi, Mayıs-Haziran, 69-82. https://www.thbb.org/media/2033/makale123.pdf
Sağlam, A. R. And Akman, M. S. (2002). Yüksek Performanslı Betonlarda İşlenebilme Açısından Çimento ve Süper Akışkanlaştırıcı Katkının Uyumu. Sika Teknik Bülten, 3-9.
Taşdemir, C. (2001). Agrega Tür ve Boyutunun Beton Performansına Etkisi. THBB Hazır Beton Mart-Nisan.
TS EN 197-1, 2002. Çimento-Bölüm 1: Genel Çimentolar- Bileşim. Özellikler ve Uygunluk Kriterleri, Türk Standartları Enstitüsü, Ankara.
TS EN 206:2013 + A1 (2017). Beton- Bölüm 1: Özellik, Performans, İmalat ve Uygunluk, Türk Standartları Enstitüsü, Ankara.
TS EN 480-10 (2001). Kimyasal Katkılar-Beton, Harç ve Şerbet İçin- Deney Metotları- Bölüm 10: Suda Çözünebilir Klorür Muhtevası Tayini. Türk Standartları Enstitüsü, Ankara.
TS 802, 2016. Beton Karışımı Hesap Esasları, Türk Standartları Enstitüsü, Ankara.
TS EN 934-2+A1 (2013). Kimyasal Katkılar – Beton, Harç ve Şerbet İçin – Bölüm 2:Beton kimyasal katkıları - Tarifler, gerekler, uygunluk, işaretleme ve etiketleme. Türk Standartları Enstitüsü, Ankara.
TS EN 1097-6, 2000. Agregaların Mekanik ve Fiziksel Özellikleri İçin Deneyler Bölüm, 6. Türk Standartları Enstitüsü, Ankara
TS EN 12350-2, 2002. Beton – Taze Beton Deneyleri- Bölüm 2: Çökme (Slamp) Deneyi, Türk Standartları Enstitüsü, Ankara.

TS EN 12390-3, 2003. Beton-Sertleşmiş Beton Deneyleri-Bölüm 3: Deney numunelerinde basınç dayanımının tayini, Türk Standartları Enstitüsü, Ankara.

TS EN 12390-6, 2010. Beton-Sertleşmiş Beton Deneyleri-Bölüm 3: Deney numunelerinin yarmada çekme dayanımının tayini, Türk Standartları Enstitüsü, Ankara.

Topçu, İ. B. (1996). Akışkanlaştırıcı ve Dona Dayanım Katkılarının Beton Özelliklerine Etkisi, TMMOB, İMO, 4. Ulusal Beton Kongresi, İstanbul, 45-54.

Topçu, İ. B., Canbaz, M. and Karakurt, C. (2006). Beton Üretiminde Kimyasal Katkı Kullanımı. Politeknik Dergisi, 9(1), 59-63. https://dergipark.org.tr/tr/pub/politeknik/issue/33019/367084#article_cite

Tunç, E. T., Alyamaç, K. E., Ragıp, İ.N.C.E. and Ulucan, Z. Ç. (2018). Investigation of mechanical properties of high-performance lightweight concrete with pumice aggregate. Engineering Sciences, 13(4), 344-353. http://dx.doi.org/10.12739/NWSA.2018.13.4.1A0425

Tunç, E. T. (2018). Strength Properties of Hardened Concrete Produced with Natural Aggregates for Different Water/Cement Ratios. Avrupa Bilim ve Teknoloji Dergisi, (14), 280-287. https://dergipark.org.tr/tr/download/article-file/608033

Tunc, E. T. 2019. Recycling of marble waste: A review based on strength of concrete containing marble waste. Journal of environmental management, 231, 86-97, https://doi.org/10.1016/j.jenvman.2018.10.034.

Tunc, E. T. and Alyamac, K. E. (2019). A preliminary estimation method of Los Angeles abrasion value of concrete aggregates. Construction and Building Materials, 222, 437-446, https://doi.org/10.1016/j.conbuildmat.2019.06.176

Yazıcı, Ş. (2003). Süper Akışkanlaştırıcıların Betondaki Bazı Fiziksel Ve Mekanik Özelliklere Etkileri, DEÜ Mühendislik Fakültesi, Fen ve Mühendislik Dergisi Cilt:5 Sayı: 1. http://acikerisim.deu.edu.tr:8080/xmlui/bitstream/handle/20.500.12397/2605/13-10.pdf?sequence=1

Yıldırım, H., Yorulmazel, V. and Ardaç, E. (1996). Süper ve Normal Akışkanlaştırıcı Katkıların Çimento ile Uyuşumu, İMO, 4. Ulusal Beton Kongresi, İstanbul, 25-33.