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Effect of air-entraining admixture usage rate on dynamic yield stress and viscosity in Portland cement systems containing urea

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Abstract

Air-entraining admixtures added to cementitious systems in order to increase freeze-thaw resistance also affect the fresh state properties of the mixture. In this study, the effect of the use of air-entraining admixtures on the rheological properties of urea-containing Portland cement systems was investigated. For this purpose, 3 different paste mixtures were prepared by adding 0.15% and 0.30% air-entraining admixtures to the control mixture containing 3% urea instead of cement. The dynamic yield stress and viscosity values of the prepared mixtures were determined in accordance with the Herschel Bulkley model. It was determined that the dynamic yield stress values of the paste mixtures increased and the viscosity values decreased with the use of air-entraining admixtures. It was understood that this behavior became more evident with the increase in the use of admixtures.

Keywords

Viscosity, flowability, loop test, thixotropy, air entraining admixture

1. INTRODUCTION

Concrete exposed to many environmental influences such as freeze-thaw [1], impact [2], abrasion and cavitation [3], high temperature [4], alkali silica effect [5], sulfate effect [6], corrosion [7], acid effect [8] and alkali-carbonate reaction [9]. In order for the concrete to serve for many years, it must be protected from these effects. Destructions occur in concrete structures exposed to the freeze-thaw cycle. The reason for this destruction is that the water leaking into the various voids in the concrete structure turns into ice at low temperature, while the volume expands by 9% [10]. One of the measures to be taken to reduce the freeze-thaw effect is to ensure impermeability and the other measure is to increase the freeze-thaw resistance of concrete by using air-entraining chemical admixtures (AEA) [11,12]. As a result of using AEA, air bubbles varying between 10 μm and 1 mm are formed [13]. These air bubbles both prevent capillary water absorption and prevent the pressure exerted on the walls by the ice mass formed by the freezing water [14]. The effect of the use of air-entraining admixtures on the fluidity properties, strength and durability performance of concrete was investigated by various researchers.

In a study conducted by Yalçınkaya and Yazıcı [15], it was stated that the fluidity of the concrete mixture increased, but the compressive strength decreased with the use of air-entraining admixtures. In another study by Ataş [16], it was reported that the use of inorganic-based air-entraining admixtures increased the compressive and flexural strength of the mortar mixture by 5% and 8%, respectively. It was emphasized that this is due to the fact that the admixture in question entrains less air and improves the flow performance of the mixture, preventing the formation of irregular air spaces. However, it was declared that the strength performance of the mixture is seriously adversely affected due to the addition of fatty alcohol and ammonium salt-based air-entraining admixtures and the greater amount of air entrainment.

In a study by Güleryüz et al. [17], the effect of adding 0.5% AEA to a mortar mixture containing 30% fly ash (FA) and 10% silica fume (SF) instead of cement on the freeze-thaw resistance, water absorption and compressive strength of the mixture was investigated. It was emphasized that the consistency, workability, permeability properties and resistance to freeze-thaw of the mixture were positively affected by the addition of air-entraining admixtures. In the study conducted by Kodak [18], it was reported that the compressive strength of the self-compacting concrete mixture decreased with the addition of 0.1% air-entraining admixture, but the flow performance increased. In the study carried out by Özerkan [19], the effects of air-entraining admixtures (0%, 0.15%, 0.3%) and fly ash (15%, 30% and 45%) on the flow performance and freeze-thaw resistance of self-compacting concrete mix were investigated. In the study, a software was developed by basing the air gap parameters of the concrete on the image analysis of the concrete surface. With the developed method, it was used to determine the air void parameters of self compacting concrete and to determine the strength effect of these parameters in freeze-thaw cycles. At the end of the study, it was stated that if the void factor value used in the evaluation of freeze-thaw resistance is less than 0.4, the void factor should not be limited to 0.2, since it can maintain its resistance to freeze-thaw. It was reported that the lowest freeze-thaw resistance was measured in the mixture without air entrainment and with the maximum fly ash content (45%). It has been declared that the highest freeze-thaw resistance is observed in the mixture that does not contain air-entraining and contains 30% fly ash, and mixtures containing 0.15% air-entraining and 45% fly ash. It was determined that the fluidity of the mixture increased with the use of air-entraining admixtures and this effect decreased with the increase in the use of fly ash. In the study by Şahin [20], effect of the use of air-entraining admixtures with 6 different chemical properties (neutralized vinsol resin, neutralized colophon resin, fatty alcohol and ammonium salt, fatty alcohol derivative, sodium salts mixture, synthetic) on the freeze-thaw damage of concrete mixtures under experimental conditions with different freezing rates was investigated. In non-air-entrained concretes, mixtures with an W/C ratio of 0.55 suffered flaking damage under all test conditions. On the other hand, the mixture with low W/C (0.40) ratio was damaged under standard freezing cycle and long freezing time conditions. It was determined that the flaking value remained below the damage criterion in fast freezing speed and slow freezing speed conditions. Air-entrained concretes, on the other hand, indicated that they provided sufficient performance under all test conditions. With the decrease of plastic viscosity values of concrete mixtures, the amount of air obtained decreased. In mixtures where the viscosity of the concretes increased over time, the amount of air decreased over time, regardless of the chemical basis of the air-entraining admixture.

As it is understood from the literature, it is very important to investigate the effect of air-entraining admixtures added to increase the freeze-thaw resistance in cementitious systems on fluidity. It was reported by Mardani-Aghabaglou [21] that the flow performance of mixtures can be directly determined by rheological parameters such as shear stress and viscosity.

In the literature, there are some studies stating that the freeze-thaw resistance of mixtures increases with the use of urea, which is an industrial product [22]. In a study conducted by Demirboğa [22], the compressive strength of mixtures prepared with urea was examined by exposing them to temperatures of -5, -10, -15 and -20 °C. As a result of the study, it was reported that the use of urea increased the compressive strength of the concrete mixture at -5 °C, but had no effect at lower temperatures. In another study, the effect of the use of antifreeze admixtures on the mechanical properties of concrete mixtures containing urea and calcium nitrate, exposed to cold weather conditions while fresh, was investigated by Polat [23]. Decreases were observed in the compressive strength of mixtures containing urea. It is understood from the literature that studies on the effect of urea use on the mechanical and durability performance of mixtures were conducted [22,23]. However, no study has been found on the effect of using urea and air-entraining admixture together on the rheological properties of cementitious mixtures. In this study, the effect of air-entraining admixture usage rate on dynamic yield stress and viscosity values of urea-containing portland cement systems was investigated. For this purpose, paste mixtures were prepared by adding different dosages of air-entraining admixture to the control mixture containing 3% urea instead of cement. The rheological properties of the mixtures were measured in accordance with the Hershel Bulkley model.

2. MATERIAL and METHOD

2.1. Materials

Within the scope of the study, CEM I 42.5R type cement (PC) produced by Bursa Cement was used. The chemical component, physical and mechanical properties of the cement supplied by the manufacturer are summarized in Table 1. Some properties of the urea and air-entraining admixture supplied by the manufacturer are presented in Table 2.

Table 1. Chemical composition and physical properties of cement

Oxide	(%)	Mechanical and physical properties		
SiO_2	18.74	Compressive strength (MPa)	1-Day	2.43
Al_2O_3	5.37		28-Day	39.3
Fe_2O_3	3.04	Setting Time (min)	Initial	201
CaO	64.11		Final	321
MgO	1.21	Fineness	Blaine specific surface (cm^2/g)	3600
Na_2O	0.34		Residual on 0.090 mm sieve (%)	0.4
K_2O	0.62		Residual on 0.045 mm sieve (%)	7.4
SO_3	2.68		specific gravity	3.15
Cl^-	0.038	Volume expansion (mm)		<1

Table 2. Some properties of urea and air-entraining admixture

Admixture	Density (g/cm^3)	pH	Colour	Physical Condition	Melting point (°C)	Solids Ratio (%)
$(CO(NH_2)_2)$	1.32	9	White	Solid	133	-
AEA*	1.01	4.66	Transparent	Liquid	-	3.91

* Air entraining admixture

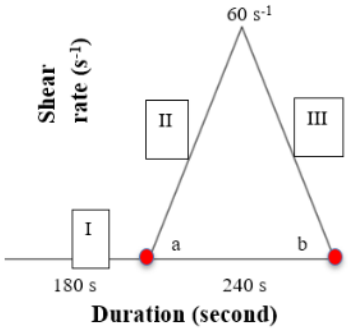
2.2. Mixture proportion

Within the scope of the study, control paste mixes with a water/cement ratio of 0.36 and containing urea at a rate of 3% by weight of cement were produced. By adding 0.15% and 0.30% of the total weight air-entraining admixture to the control mixture, 2 more batches of paste mixture were prepared. The denotation of the mixtures was made according to the use of air-entraining admixtures. For example, the control mixture without air-entraining admixtures is shown as PC-0%. The paste mixture containing 0.15% of the total weight of air-entraining admixtures was denoted PC-0.15%.

After urea and water were mixed at 62 rpm for 30 seconds, cement was added and mixed at the same speed for another 30 seconds. Then, air-entraining admixture was added and mixed at 62 rpm for 30 seconds. The parts of the mixture adhering to the bowl were cleaned with the help of a spatula and homogeneous mixing was ensured. Then, the mixture was taken into a rheometer measuring cup by mixing at 125 rpm for 120 seconds.

2.3. Test methods

The method followed in determining the dynamic yield stress and viscosity values of paste mixtures prepared within the scope of the study is explained in detail in Figure 1. In addition, the shear stress-shear rate and viscosity-shear rate graphs of the control mixture are shown in Figure 1 as an example.



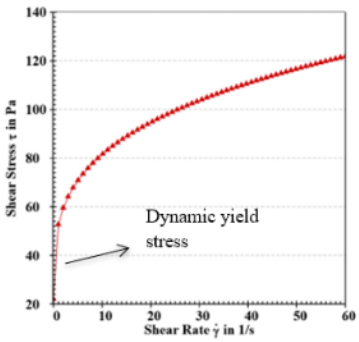
Step I: The rheological measurement process was applied to the mixture.

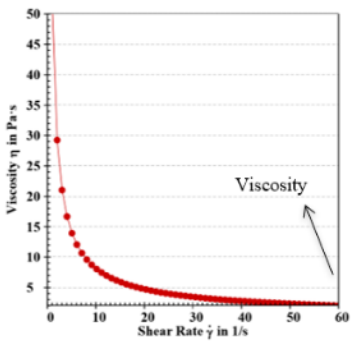
- The dynamic yield stress of the mixture was measured at the point indicated as point 'a' at the beginning of the period.
- The viscosity was measured at the point indicated as point 'b' at the end of the period.

$$\tau = \tau_o + b.\dot{\gamma}^P \quad (1)$$

τ_o: dynamic yield stress	$\dot{\gamma}$: Shear rate
b: Herschel-Bulkley coefficient	P: Herschel-Bulkley index

Step II: The raw values obtained as a result of the rheological measurement process were analyzed by Herschel Bulkley analysis.





Step III: Shear stress-shear rate and viscosity-shear rate graphs were created through the values obtained through the Herschel Bulkley analysis.

Figure 1. Determination of dynamic yield stress and viscosity values of paste mixes

3. DISCUSSION AND CONCLUSION

The dynamic yield stress and viscosity values of the mixtures are given in Figures 2–4. As seen in Figures 2–4, a 1.6-fold increase in dynamic yield stress value was observed with the addition of 0.15% air-entraining admixture in cement paste mixtures containing urea. In the case of 0.30% air-entraining admixture use, the dynamic yield stress value increased by 215% and 21%, respectively, compared to the mixtures using 0% and 0.15% air-entraining admixtures. Similar results were reported by other researchers for urea-free mixtures [24-27]. Huang et al. [27], the effect of the combined use of polycarboxylate-based water-reducing admixture, rosin resin-type air-entraining admixture and powder viscosity-regulating admixture on the rheological properties of self-compacting concrete mixture was investigated. It was stated that the addition of air-entraining admixture causes an increase in the yield stress of the mixture and a decrease in the plastic viscosity, while weakening the shear-thickening behavior due to the high air content. It was emphasized that when the air content reaches 8.7%, shear thickening behavior completely disappears and shear thinning behavior occurs.

As can be seen from Figures 2–4, an 18% decrease in viscosity value was measured by adding 0.15% air-entraining admixture to cement paste mixtures containing urea. In the case of 0.30% air-entraining admixture use, the viscosity value decreased by 26% and 10%, respectively, compared to mixtures using 0% and 0.15% air-entraining admixtures. Similar results for urea-free mixtures were reported by other researchers [28-32], it was reported that the plastic viscosity values of concrete mixtures containing recycled concrete aggregate using air-entraining admixtures decreased.

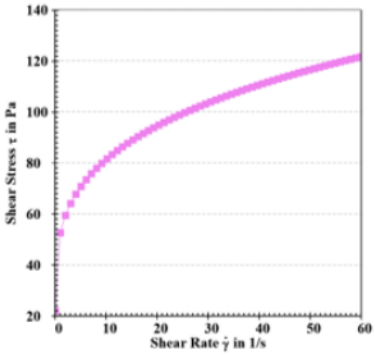
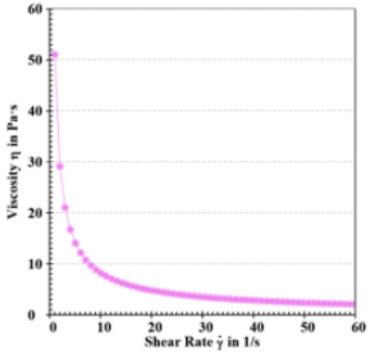
Mixture	Dynamic Yield Stress (Pa)	Viscosity (Pa.s)
PC-0%		
	22.1	51.1

Figure 2. Rheological measurement results (PC-0% mixture)

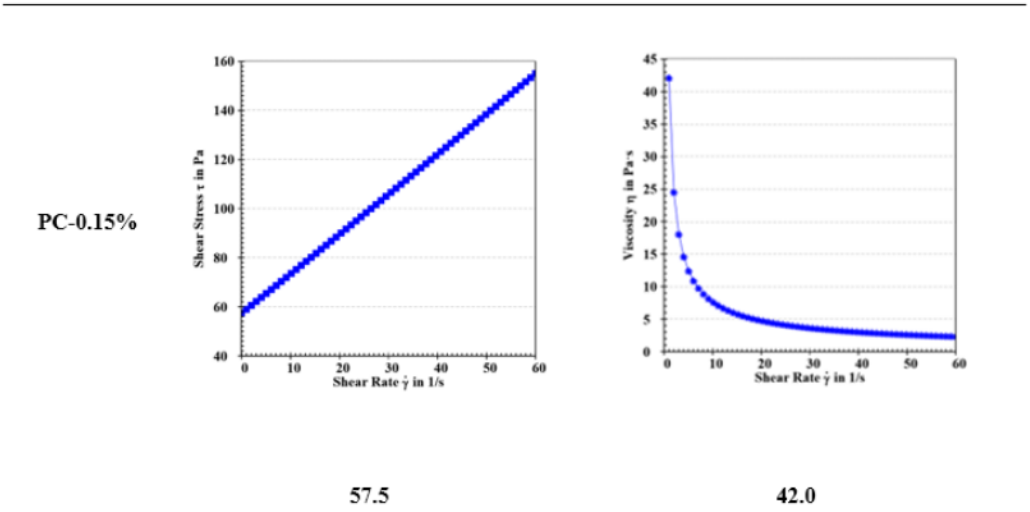


Figure 3. Rheological measurement results (PC-0.15% mixture)

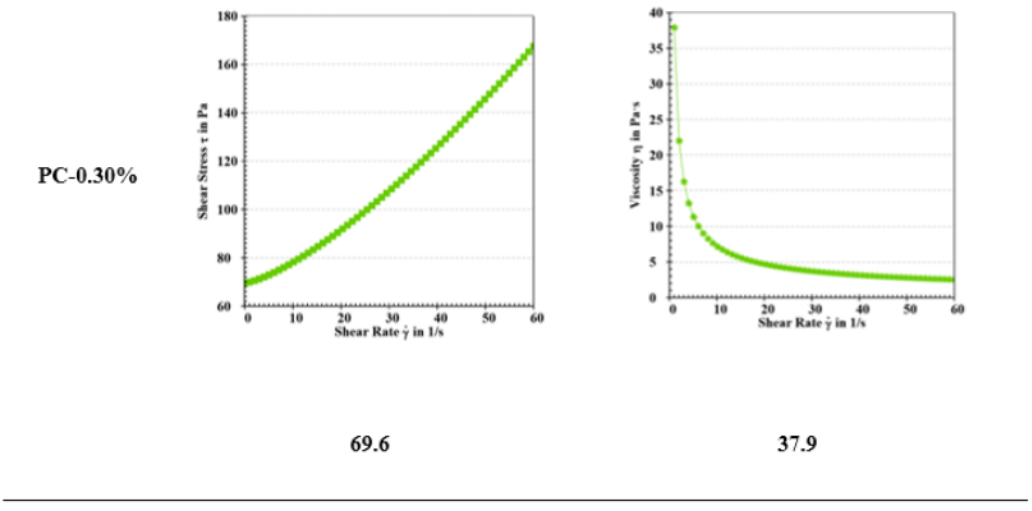


Figure 4. Rheological measurement results (PC-0.30% mixture)

4. CONCLUSION

The results obtained in line with the materials used and the methods applied within the scope of the study are presented below.

- In cement paste mixtures containing urea, the dynamic yield stress values increased with the use of air-entraining admixtures and the increase in the usage rate.
- In cement paste mixtures containing urea, the viscosity values decreased with the use of air-entraining admixtures and the increase in the usage rate.

DATA AVAILABILITY STATEMENT

All data, models, and code generated or used during the study appear in the submitted article.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST/COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

[1]. Akcaozoglu, K., & Guldur, Ş. E. (2017). The Investigation of the Effect of Micronized Calcite and Fly Ash Addition on the Concrete Properties. Afyon Kocatepe University Journal of Science and Engineering Sciences, 17(2), 658-668. (In Turkish).
[2]. Alkayıs, M. H., & Basyigit, C. (2021). Effect of Fiber Additive on Concrete Impact Strength European Journal of Science and Technology, (24), 455-462.
[3]. Baradan, B., and Aydın, S. (2013). Betonun Dürabilitesi, Hazır Beton Kasım-Aralık 2013 Makale Article.
[4]. Topçu İ.B. ve Demir. A., 2007, Yüksek Sıcaklık Uygulama Süresinin Harç Özelliklerine Etkisi, Ulusal Beton Kongresi, Sakarya İnşaat Mühendisleri Odası.
[5]. Ramyar. K., (2013). Betonda Alkali-Silis Reaksiyonu, Hazır Beton Kasım-Aralık 2013 Article Makale.
[6]. Ilıca. T., (2008). Farklı Çimentolarla Üretilen Betonlarda Sülfat Etkisi ve Klorür Geçirimliliği, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Bölümü Yapı Anabilim Dalı Yüksek Lisans Tezi, İstanbul.
[7]. Yavuz. R., Gunaydın. O. ve Gucluer. K., (2019). Donatılı Betonda Korozyon ve Aderansın Araştırılması, KSÜ Mühendislik Bilimleri Dergisi, 22, Özel Sayı, 2019 KSU J Eng Sci, 22, Special Issue, 2019 Uluslararası İleri Mühendislik Teknolojileri Sempozyumu (ISADET).
[8]. Yurt. U., Dundar B. ve Cınar. E., (2020). Jeopolimer Betonlarda Sülfürik Asit Etkisinin Araştırılması, Düzce Üniversitesi Bilim ve Teknoloji Dergisi Araştırma Makalesi.
[9]. Mather, B., (2004). Concrete Durability. Cement and Concrete Composites, 26: 3-4
[10]. Baradan, B., Turkel. S., Yazıcı. H., Un. H., Yigiter. H., Felekoglu. B., Tosun. K., Aydın. S., Yardımcı. YM., Topal. A., Oztürk AU. (2012). Beton. İzmir, Türkiye, Dokuz Eylül Üniversitesi Mühendislik Fakültesi Yayınları.
[11]. Snyder. KA., (1998). "A numerical test of air void spacing equations". Advanced Cement Based Materials, 8, 28-44.
[12]. Sahin H.G., Mardani, A., Ozen S. & Emin, A., (2022). Utilization of high-range water reducing admixture having air-entraining agents in cementitious systems. Journal of Building Engineering, 105565.
[13]. Erzengin. G., (2010). Kimyasal Katkıların Çimento Bazlı Malzemelerin Dayanımına,Reolojisine ve Mikro Yapısına Etkileri, Ankara Üniversitesi Fen Bilimleri Enstitüsü Kimya Mühendisliği Anabilim Dalı Doktora Tezi, Ankara.
[14]. Neville AM., (1997). Properties of Concrete. London, England, John Wiley & Sons Inc.
[15]. Yalcınkaya. C. ve Yazıcı., H., (2009). Hava Sürükleyici Katkının Kendiliğinden Yerleşen Çelik Lifli Betonun İşlenebilirliğine ve Basınç Dayanımına Etkisi
[16]. Atas, Z. (2013). Investigation of Mechanical Behavior of Cement Mortars Containing Air Entraining Agent and Fibers Under Freeze-thaw Effect, Gumushane University Institute of Science and Technology (Master Thesis) (In Turkish).
[17]. Guleryuz. E., Ozen. S. ve Aghabaglou. A.M., (2020). Mineral Katkı Kullanımının Hava Sürükleyici Katkılı Çimentolu Harçların Taze ve Sertleşmiş Hal Özeliklerine Etkisi, Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi.
[18]. Kodak. İ., (2019). Hava Sürükleyici ve Uçucu Kül Katkılarının Kendiliğinden Yerleşen Betonun İşlenebilirliğine ve Basınç Dayanımına Etkisi, Kütahya Dumlupınar Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi.
[19]. Ozerkan. N., (2009). Evaluation of Air Void Parameters of Fly Ash Incorporated Self Consalidating Concrete by Image Processing, Middle East Technical University in Partial Fulfillment of The Requirements for The Degree of Doctor of Philosophy in Civil Engineering.
[20]. Sahin. Y., (2013). Characterization of Air Entraining Admixture and Effect of Test Conditions on Freezing-Thawing Damage of Concrete, Istanbul Technical University Institute of Science and Technology Thesis (PhD).

[21]. Mardani-Aghabaglou. A., (2016). Portland Çimentosu ve Süperakışkanlaştırıcı Katkı Uyumunun İncelenmesi, Ege Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Anabilim Dalı Doktora Tezi, İzmir.
[22]. Demirboga. R., Karagol. F., Polat. R. and Kaygusuz. M.A., (2014). The effects of urea on strength gaining of fresh concrete under the cold weather conditions, Construction and Building Materials, 64(2014)114-120
[23]. Polat. R., (2016). The effect of antifreeze additives on fresh concrete subjected to freezing and thawing cycles , Cold Regions Science and Technology , 127 (2016) 10–17
[24]. Rahman, M. A., & Nehdi, M., (2003). Effect of geometry, gap, and surface friction of test accessory on measured rheological properties of cement paste. Materials Journal, 100(4), 331-339.
[25]. Struble, L. J., & Jiang, Q., (2004). Effects of air entrainment on rheology. Materials Journal, 101(6), 448-456.
[26]. Łaźniewska-Piekarczyk. B., (2013). The influence of chemical admixtures on cement hydration and mixture properties of very high performance self-compacting concrete. Construction and building materials, 49, 643-662.
[27]. Huang. F., Li. H., Yi. Z., Wang. Z., & Xie. Y., (2018). The rheological properties of self-compacting concrete containing superplasticizer and air-entraining agent. Construction and Building Materials, 166, 833-838.
[28]. Szwabowski, J., & Łaźniewska-Piekarczyk, B., (2008). The increase of air content in SCC mixes under the influence of carboxylate superplasticizer. Cement Wapno Beton, 4, 205-215.
[29]. Tattersall G. H., Banfill P. F., (1983). The rheology of fresh concrete.
[30]. K.-K. Yun, S.-Y. Choi, J.H. Yeon., (2015). Effects of admixtures on the rheological properties of high-performance wet-mix shotcrete mixtures, Constr. Build. Mater. 78 (2015) 194–202
[31]. X. Zhang, H. Zhang, H. Gao, Y. He, M. Jiang, (2019). Effect of bubble feature parameters on rheological properties of fresh concrete, Constr. Build. Mater. 196 (2019) 245–255.
[32]. Bizinotto. M.B., Faleschini. F., Fernández. C.G.J., Hernández. D.F.A., (2017). Effects of chemical admixtures on the rheology of fresh recycled aggregate concretes, Construction and Building Materials, 151 (2017) 353–362