Tamap Journal of Engineering
http://www.tamap.org/

doi:10.29371/2019.3.118
Volume 2019, Article ID 118
Research Article

Material Selection Processes of Ready Mixed Concrete Producers and Effects of Constituents on Fresh and Hardened Properties

Ömer Arıöz[1,*]

[1]AAcademy RMC, Eskisehir, Turkey

Received: 20.11.2019 • **Accepted**: 29.12.2019 • **Published Online:** 31.12.2019

Abstract: The effects of raw materials that a ready mixed concrete producer will use in concrete production on fresh and hardened concrete properties were investigated. Concrete mixtures were designed and tested in both fresh and hardened state to provide the desired properties in the most appropriate way. Five different mixtures were designed with three different hyper plasticizing (HP) chemical admixtures and two different super plasticizing (SP) chemical admixtures. Test results indicated that initial slump values of the mixtures were ranged between 20 cm and 23 cm. The slump retentions of the mixtures produced by SP chemical admixtures were slightly lower than those produced by HP chemical admixtures. Improving the slump retention values of the super plasticizing admixtures used in this study can make these types of admixtures preferable by the concrete producer. While the handling levels of the mixtures produced with HP chemical admixtures were medium, the mixtures produced with SP chemical admixtures were good. It can be suggested to increase the handling levels of mixtures produced with HP and to increase the flowability of the mixtures produced with SP with minor changes that can be made in the content of the relevant admixture. Compressive strength test results indicated that 1-day compressive strength values of the mixtures were found as normal except for a mixture. Both 7-days and 28-days strengths of mixtures produced with HP chemical admixtures were slightly higher than those produced with SP chemical admixtures. Results showed that plasticizing chemical admixtures can affect both early and later age strengths of ready mixed concrete mixtures even for equal water/binder ratios.

***Keywords**:* Ready mixed concrete, Plasticizing chemical admixture, Flowability, Workability, Compressive strength.

1. Introduction

Ready mixed concrete (RMC) is one of the most widely used composite construction material produced by mixing basically aggregate, cement, and water by mixing operations in automated batching plants. It is delivered to the customer in fresh form after being produced in the ready mixed concrete batching plant [1]. Today, apart from these three main components, chemical admixtures, mineral admixtures and fibers have also been used frequently in the production of ready mixed concrete since many benefits can be obtained [1-7]. RMC production process begins with the supply of raw materials to the batching plant and storing them under suitable conditions. Then the raw materials are weighed and sent to the mixer in a certain order [1,8]. Fig. 1 indicates production process in a batching plant schematically [1].

* Correspondence: info@betonakademisi.com

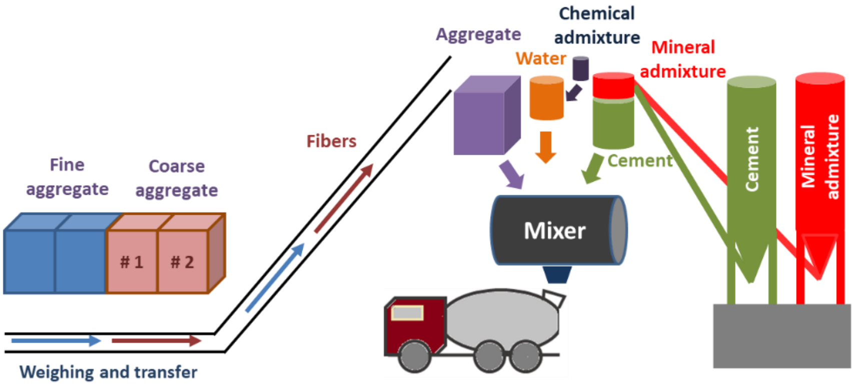

Fig.1. Production process in a batching plant [1]

RMC is a different construction material having two important stages; plastic in the first 2-3 hours and elastic after setting-hardening. In other words, it is in a fresh state in a few hours, then hardened and starts to carry loads. It should be marked that RMC should satisfy demanded properties in both states. A properly designed RMC mixture should be adequately workable when it is still in fresh state. Workability of RMC can be expressed as ease of mixing, transporting, pumping, placing, consolidating, compacting, and finishing without segregation, without excess bleeding and without extra effort. Fresh RMC should have an appropriate setting time to allow a proper consolidation and finishing. Moreover, a properly designed RMC should also fulfill the required strength parameters and possess good durability in hardened state [9]. Hardened RMC should be volumetrically stable material.

Ready mixed concrete producers always want to choose the most suitable raw materials in terms of fresh and hardened ready mixed concrete properties and to produce economical concrete. Therefore, they constantly experiment with different raw materials and examine the fresh and hardened properties of ready mixed concrete. Cement, aggregate, and water are the main constituents of RMC production. After determining the main raw materials to be used in concrete production, the next step is usually which chemical admixtures will be used with these inputs. Plasticizers constitute the majority of the chemical admixtures used in RMC production. Plasticizers are used in RMC production in order to increase the fluidity of the mixture without changing the water/cement ratio. They can also be used to achieve higher strength values by reducing water/cement ratio for a certain fluidity. For a certain fluidity and water/cement ratio, use of plasticizer provides technical and economic benefits by reducing the cement content in the mix [1,2,5,6,9]. Today, RMC producers have also used mineral admixtures such as fly ash, ground granulated blast furnace slag (GGBFS), and silica fume in order to improve or modify both fresh and hardened concrete properties [1,7]. Finally, different mix designs are made and tested to decide how much of these raw materials of ready mixed concrete will be included in the mixture in order to meet the desired properties from fresh and hardened concrete.

In this experimental study, five different concrete mixtures were prepared and tested in order to facilitate the raw material selection of the ready mixed concrete producer and to provide the desired properties in the most appropriate way.

2. EXPERIMENTAL STUDY

Concrete mixtures were designed and tested in both fresh and hardened state in order to determine the effects of plasticizing chemical admixtures on the concrete properties. Five different concrete mixtures were designed by three different polycarboxylate based hyper plasticizing chemical admixtures, two different super plasticizing chemical admixtures, CEM I/42,5 R type Portland cement, ground granulated blast furnace slag as mineral admixture, crushed limestone, and water. The properties of the aggregate were determined and evaluated according to relevant standards TS EN 933-1:2012(EN) and TS 706 EN 12620+A1 [10,11]. Table 1. lists the properties of the aggregates used in the study.

Table 1. Properties of aggregates used in the study

Aggregate	Specific Gravity	Water Absorption Capacity (%)
Fine Aggregate	2.69	1.4
Coarse Aggregate (7mm-15mm)	2.71	0.5
Coarse Aggregate (15mm-22mm)	2.72	0.5

The grain size distribution of the fine aggregate is more important than that of the coarse aggregate in the concrete transmitted by the pump. Fig.2 shows particle size distribution curves of both fine aggregate recommended for use in pumped concrete and fine aggregate used in this study. Fig.3 presents the particle size distribution curves of both mixture aggregate recommended for use in pumped concrete and mixture aggregate used in this study.

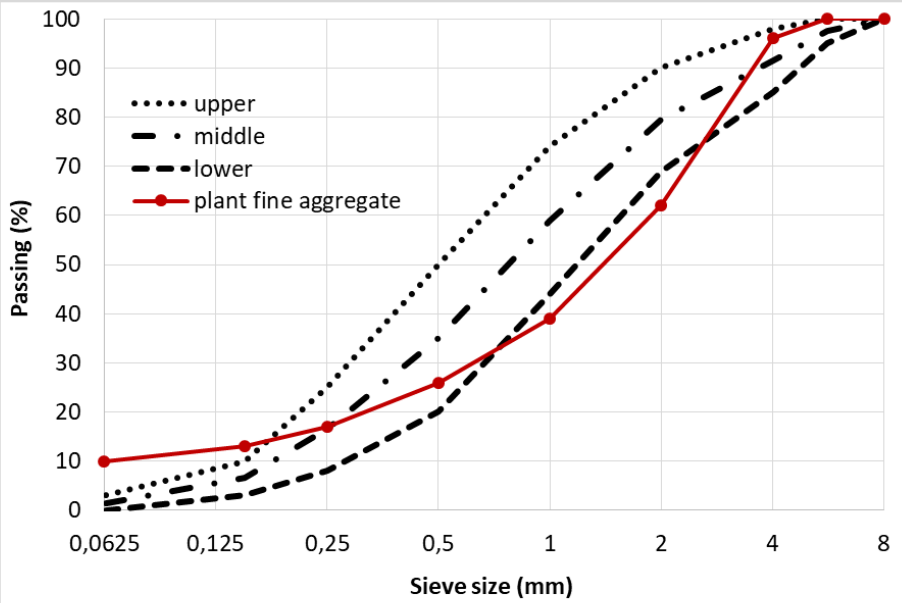

Fig.2. Particle size distribution curves of fine aggregates recommended for use in pumped concrete

According to the results of sieve analysis of fine aggregate, it was clear that the amount passing through the 0.063 mm sieve was quite high, and the amount passing through the 1 and 2 mm sieves was somewhat low. In order to have a more suitable grain size distribution of fine aggregate for use in pumped concrete, it is proposed to make revisions in the aggregate production process.

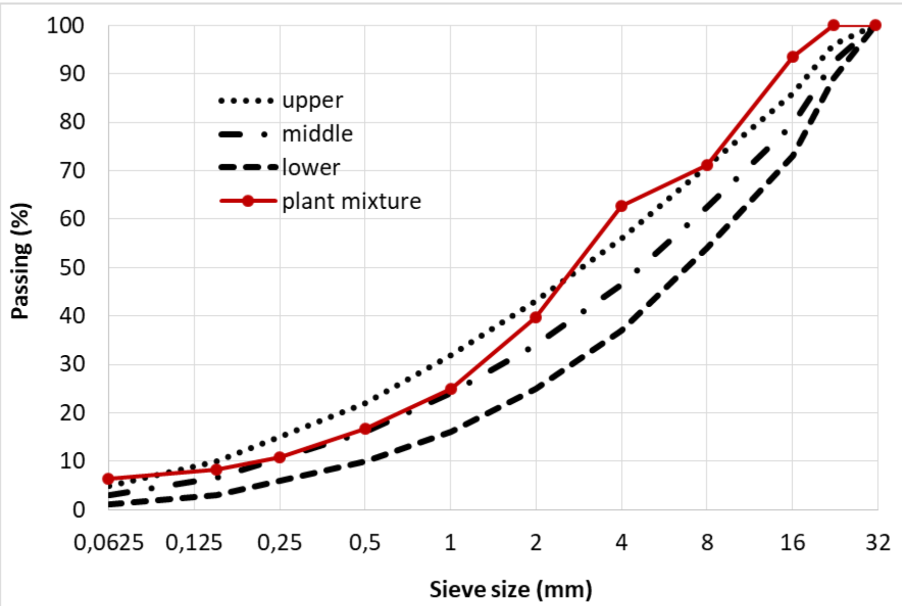

Fig.3. Particle size distribution curves of mixture aggregates recommended for use in pumped concrete

According to sieve analysis result, it can be said that grain size distribution of mixture aggregate was in limits for concrete mixtures to be pumped. It should be marked that the concrete mixture will need more water since the particle size distribution of the mixture aggregate remains mostly on the finer side of the limits.

The three different hyper plasticizing chemical admixtures used in the production of concrete samples were denoted as HP1, HP2, and HP3. The two different super plasticizing chemical admixtures used in this study were denoted as SP1 and SP2. Mix designs of concretes were carried out according to relevant standard, TS 802 [12]. Table 2 shows the mix proportions of different concrete mixtures.

Table 2. Mix proportions of different concrete mixtures

Materials and Mixtures	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5
Cement	200	200	200	200	200
Blast Furnace Slag	130	130	130	130	130
Water	184	184	190	198	198
Chemical Admixture	1.98	1.98	4.95	4.95	4.95
Fine Aggregate	1186	1186	1186	1186	1186
Coarse Aggregate (7-15 mm)	188	188	188	188	188
Coarse Aggregate (15-22 mm)	492	492	492	492	492
Plasticizing Chemical Admixture	HP1	HP2	HP3	SP1	SP2

Flow abilities of the freshly mixed concretes were measured by means of testing of mixture consistencies by slump tests which is defined in TS EN 12350-2 [13]. The slump values of the mixtures were measured when the mixtures were made and after 30 minutes. The compressive strength tests were carried out on 150 mm cubic specimens at the ages of 1, 3, 7 and 28 days. The effects of raw materials that a ready mixed concrete producer will use in concrete production on fresh and hardened concrete properties were investigated.

3. RESULTS AND DISCUSSIONS

A properly designed RMC mixture should be adequately workable when it is still in fresh state. Workability is related to the effort required to place a RMC mixture and it is determined largely by the overall work needed to initiate and maintain flow. Slump values of the fresh concrete mixtures were measured in order to examine workability and workability retention. Fig.4 indicates slump values of the mixtures.

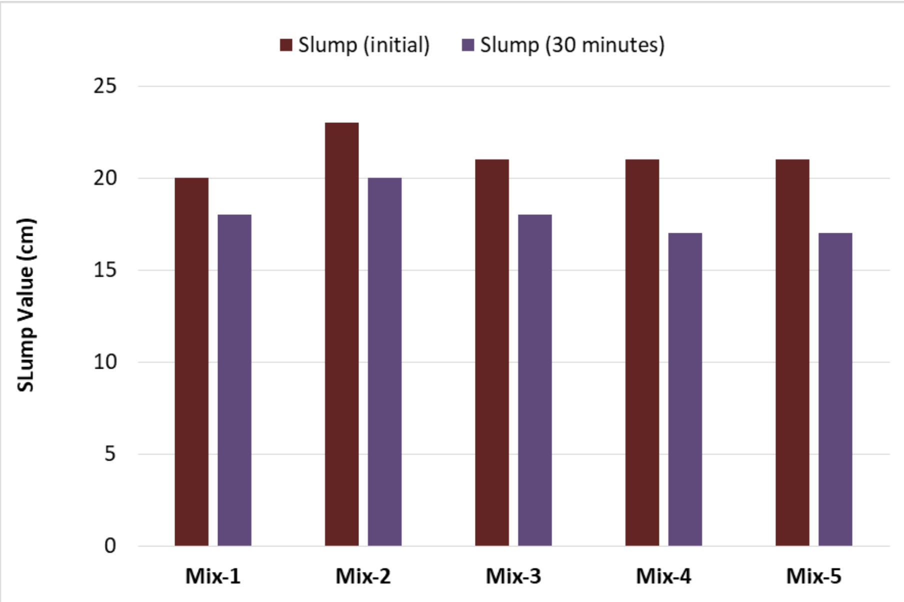

Fig.4. Slump values of the concrete mixtures

Concrete mixtures Mix-1, Mix-2, and Mix-3 were produced by HP (hyper plasticizing) chemical admixture and MIX-4 and Mix-5 were produced by SP (super plasticizing) chemical admixture. Test results indicated that initial slump values of the mixtures were ranged between 20 cm and 23 cm. Maximum slump value was observed as 23 cm for Mix-2. The slump values measured at 30 minutes after mixing varied between 17 cm and 20 cm. It should be marked that the slump retentions of the mixtures produced by super plasticizing (SP) chemical admixtures were slightly lower than those produced by hyper plasticizing (HP) chemical admixtures. For example, while the slump value of Mix-3 decreased from 21 cm to 18 cm for 30 minutes, the slump value of Mix-4 decreased from 21 cm to 17 cm. It can be marked that, improving the slump retention values of the super plasticizing admixtures used in this study can make these types of admixture preferable by the concrete producer.

Workability of RMC includes two parameters, consistency and cohesiveness. Consistency of concrete can be defined as the ability of concrete to flow and the better consistency means better workability and better performance. Cohesiveness reflects the ability of fresh concrete to hold all the ingredients together uniformly. A cohesive fresh concrete hold aggregate and water in the mixture well. Thus, the risk of bleeding and segregation is reduced in a cohesive fresh concrete [14]. Therefore, the behavior of fresh concrete was also observed in this study. Table 3 lists the some features of the mixtures with observations.

Table 3. Some features of the mixtures with observations

Feature/observation	Mix-1	Mix-2	Mix-3	Mix-4	Mix-5
water/binder (w/b) ratio	0,56	0,56	0,58	0,60	0,60
Air content (%)	184	184	190	198	198
Chemical admixture (%)	2	1.8	1.9	3.3	2.8
Chemical admixture	HP1	HP2	HP3	SP1	SP2
Observations on fresh concrete	Medium handling, low flowability	Medium handling, low flowability	Medium handling, high flowability	Good handling, medium flowability	Good handling, medium flowability

It was observed that while the handling levels of the mixtures produced with hyper plasticizing (HP) chemical admixtures were medium, the mixtures produced with super plasticizing (SP) chemical admixtures were good. It was also observed that while the flowability levels of the mixtures produced by super plasticizing (SP) chemical admixtures were medium, only Mix-3 has a high level of fluidity in mixtures produced with hyper plasticizing (HP) chemical admixtures. According to these observations, it can be suggested to increase the handling levels of mixtures produced with HP (Mix-1, Mix-2, Mix-3) and to increase the flowability of the mixtures produced with SP (Mix-4, Mix-5) with minor changes that can be made in the content of the relevant admixture.

Compressive strength is the most commonly used test to measure the quality of RMC. Therefore, a properly designed RMC should also fulfill the required strength parameters. The compressive strength is the maximum resistance to axial loads applied on a hardened RMC sample. For fully compacted RMC mixtures, strength and other desirable properties are governed by amount of mixing water per cement [5,6,9,15]. For a normal strength RMC mixture, compressive strength is inversely related to the water/cement ratio of the mixture. In this study, compressive strength values of the mixtures were determined at the ages of 1, 3, 7, and 28 days. Here, 1, 3 and 7-day strengths represent the early age strength of the mixture and 28-day strengths represent later age strength. Fig.5 presents compressive strength developments of the concrete mixtures.

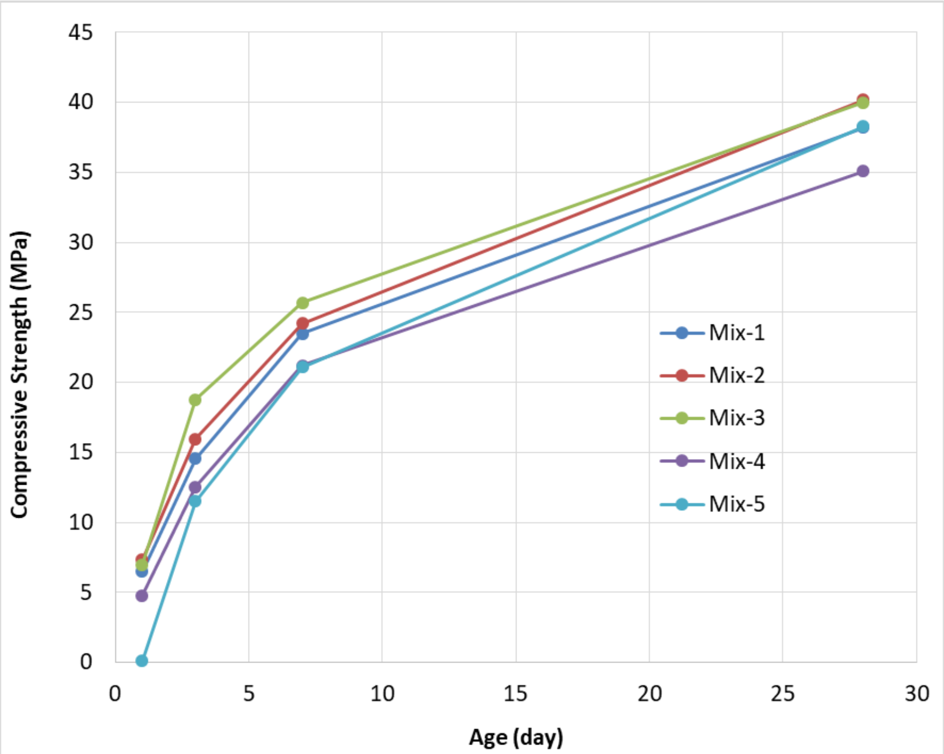

Fig.5. Compressive strength developments of the concrete mixtures

Compressive strength test results indicated that 1-day compressive strength of the mixtures were found normal except for Mix-5 which had a 1-day compressive strength of 0.1 MPa. Mix-5 was produced by SP which may cause such a low very early age compressive strength. It can be suggested to increase the 1-day strength of Mix-5 with minor changes that can be made in the content of the relevant admixture. 3-days compressive strength values ranged between 12 and 19 MPa. It was found that 3-days strengths of the mixtures produced with HP chemical admixtures were significantly higher than those produced with SP chemical admixtures. For example, 3-days compressive strength values of Mix-3 and Mix-4 were measured as 18.8 and 12.6 MPa, respectively. 7-days strength values varied from 21 to 26 MPa for the mixtures. It should be noted that 7-days strengths of mixtures produced with HP chemical admixtures were slightly higher than those produced with SP chemical admixtures. For example, 7-days strengths of Mix-1 and Mix-5 were measured as 23.5 and 21.1 MPa, respectively. The compressive strength values of the mixtures measured at the age of 28 days ranged between 35.1 and 40.2 MPa. It should be marked that the strengths of the mixtures produced with HP chemical admixtures were slightly higher than those produced with SP chemical admixtures. For example, the compressive strength values of Mix-3 and Mix-5 were measured as 40 and 38.1 MPa. This difference can be attributed to difference between the water/binder (w/b) ratios of the mixtures produced with HP chemicals and SP chemicals. It can be noted that, the water/binder (w/b) ratios of Mix-3 and Mix-5 were recorded as 0.58 and 0.60, respectively. Results showed that plasticizing chemical admixtures can affect both early and later age strengths of ready mixed concrete mixtures even for equal water/binder ratios. For example, 28-days compressive strength values of Mix-4 and Mix-5 were recorded as 35.1 and 38.3 MPa, respectively even the mixtures Mix-4 and Mix-5 have equal w/b ratio.

4. CONCLUSIONS

In the experimental study flowability of freshly mixed concrete and compressive strength of hardened concrete were measured. Raw materials of concrete production were also tested. In order to have a more suitable grain size distribution of fine aggregate for use in pumped concrete, it is proposed to make revisions in the aggregate production process. Test results indicated that initial slump values of the mixtures were ranged between 20 cm and 23 cm. The slump values measured at 30 minutes after mixing varied between 17 cm and 20 cm. It should be marked that the slump retentions of the mixtures produced by super plasticizing (SP) chemical admixtures were slightly lower than those produced by hyper plasticizing (HP) chemical admixtures. Improving the slump retention values of the super plasticizing admixtures used in this study can make these types of admixture preferable by the concrete producer. While the handling levels of the mixtures produced with hyper plasticizing (HP) chemical admixtures were medium, the mixtures produced with super plasticizing (SP) chemical admixtures were good. it can be suggested to increase the handling levels of mixtures produced with HP and to increase the flowability of the mixtures produced with SP with minor changes that can be made in the content of chemicals. Compressive strength is the most commonly used test to measure the quality of RMC. Test results indicated that 1-day compressive strength of the mixtures were found normal except for Mix-5 which had a 1-day compressive strength of 0.1 MPa. It should be noted that 7-days strengths of mixtures produced with HP chemical admixtures were slightly higher than those produced with SP chemical admixtures. The compressive strength values of the mixtures measured at the age of 28 days ranged between 35.1 and 40.2 MPa. It should be marked that the strengths of the mixtures produced with HP chemical admixtures were slightly higher than those produced with SP chemical admixtures. Results showed that plasticizing chemical admixtures can affect both early and later age strengths of ready mixed concrete mixtures even for equal water/binder ratios.

REFERENCES

[1] Arioz O. “Ready Mixed Concrete”. CE 447 Course Class Notes, Hasan Kalyoncu University, Gaziantep, Turkey, 2017.

[2] Arioz O. “Value Added Products in Ready Mixed Concrete Industry”. CE …. Course Class Notes, Hasan Kalyoncu University, Gaziantep, Turkey, 2017.

[3] Arioz O. “Properties of Fresh and Hardened Ready Mixed Concrete”. CE …. Course Class Notes, Hasan Kalyoncu University, Gaziantep, Turkey, 2018.

[4] Arioz, O., Özelmacı Durmaz, Ç.Ö., Arıöz, E. (2018). “Value Added Products for Ready Mixed Concrete Industry and Use of Chemical Admixtures”. Hasan Öktem (Ed.), in Current Approaches in Engineering and Architecture (pp. 9-20). SRA Academic Publishing, Turkey. ISBN: 978-605-69047-2-1.

[5] Arioz, O., Özelmacı Durmaz, Ç.Ö., Arioz, E. (2018). “Effects of Chemical and Mineral Admixtures on Fresh and Hardened Ready Mixed Concrete Properties”. Hasan Öktem (Ed.), in Current Approaches in Engineering and Architecture (pp. 21-32). SRA Academic Publishing, Turkey. ISBN: 978-605-69047-2-1.

[6] Arioz, E., Arioz, O. (2018). “Ready Mixed Concrete Constituent Materials; Plasticizing Chemical Admixtures and Effects on Fresh and Hardened Properties”, Eskişehir Technıcal University Journal of Science and Technology A-Applied Sciences and Engineering, 19(4), 982–990.

[7] Arioz, O., Özelmacı Durmaz, Ç.Ö., Arioz, E. (2019), "Use of Mineral Admixtures in Ready Mixed Concrete Production". Bülent Kırmızı and Bahar İşigüzel (Eds.) in Turkey Vision: Multidisciplinary Studies 2019 (p. 173-177). Ekin Yayınevi, Turkey. ISBN: 978-605-327-870-2.

[8] Özelmacı Durmaz, Ç.Ö., Arioz, E., Arioz, O. (2019). "Process of Ready Mixed Concrete', 6th International Multidisciplinary Studies Congress, 165-168, Gaziantep-Turkey, April 26-27. ISBN: 978-605-7602-50-3.

[9] Arioz, O., Arioz, E. "The Role of Chemical Admixtures in Ready Mixed Concrete Mixtures", IV. International Ceramic, Glass, Porcelain Enamel, Glaze and Pigment Congress, 312-318, 2018, Eskisehir, Turkey.

[10] TS EN 933-1:2012(EN). "Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method", Ankara, 2012.

[11] TS 706 EN 12620+A1. "Aggregates for concrete", Ankara, 2009.

[12] TS 802. "Design of concrete mixes", Ankara, 2016.

[13] TS EN 12350-2. "Testing fresh concrete - Part 2: Slump test", Ankara, 2010.

[14] Zongjin, L. "Advanced Concrete Technology". John Wiley and Sons Inc., New Jersey. 2011.

[15] Kosmatka, S.H., Kerkhoff, B., and Panarese, W.C. (2003). Design and Control of Concrete Mixtures. Portland Cement Association, Illinois.