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Investigation of the Efficiency of Ultra High Range Water Reducing Admixture in Roller Compacted Concrete Production

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Abstract

In this study, roller compacted concretes were produced by using polycarboxylate-based third generation high-performance mortar and concrete admixture, which provides ultra-high range water reduction and long workability time. In roller compacted concrete production, the chemical admixture dosage was 1%, which was the maximum dosage recommended by the manufacturer, and the amount of water used was reduced by 10, 20, 30 and 40% compared to the concrete produced without the use of concrete admixture. The physical and mechanical properties of the roller compacted concrete specimens were investigated. When the ultra-high range water reducer was used as 1% of the cement weight in the production of roller compacted concrete, optimum values in terms of unit weight, compressive strength, water absorption, ultrasonic pulse velocity and dynamic modulus of elasticity were obtained by reducing the mixing water by 10%. Although the water/cement ratio decreased, further reduction in water amount resulted in a decrease in compressive strength and affected the concrete quality negatively.

Keywords: Compactibility, chemical admixture, compressive strength, roller compacted concrete, water reducer.

1. INTRODUCTION

Mechanical properties of roller compacted concrete (RCC) are affected by water/binder ratio, cement content, mineral admixture and aggregate composition, as in conventional concretes [1, 2]. Roller compacted concretes are dry mixtures compared to ordinary Portland cement concretes and need to be compacted in order to reach their final shape, a proper consistency must be provided in these concretes so that the vibrating compaction hammer is not damaged and the compression energy can be reduced [3]. Although chemical admixtures used in conventional concrete production can also be used in roller compacted concretes, working with a much drier consistency in RCCs creates differences in the properties of fresh concrete and the admixture dosage may need to be changed to achieve the desired concrete properties. Workability of concrete is considered to consist of cohesion, compactibility, resistance to segregation, workability retention, water reduction and consistency; the improvement in workability for a particular mixture varies depending on the internal friction angle, the amount of air in the concrete, the type of admixture and its dosage, as well as these components [4, 5]. Roller compacted

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concretes exhibit abnormal behavior in terms of mechanical strength, as indicated by deviations from Abrams' law, and it is argued that the water/binder ratio is not a comprehensive parameter to explain the overall concrete behavior and trends [5].

Various mineral admixtures such as fly ash, silica fume, rice husk ash can be used in roller compacted concrete, as well as chemical admixtures such as plasticizers, set accelerators and retarders [6-12]. According to the Concrete Roads Technical Specification [13], air-entraining, water-reducing, high-range water-reducing, set retarding chemical admixtures and concrete admixtures that provide long workability time are used in production of concrete pavements, these chemical admixtures used to improve concrete properties must comply with TS EN 934-1 [14] and TS EN 934-2 [15] standards. Although production with admixtures is not required in roller compacted concrete applications, the use of admixtures is preferred to improve the properties of fresh and/or hardened concrete [16].

Hazaree [5] aimed to explain the roles of different chemical admixtures in affecting the workability and strength performances of RCC, and found that the amount of air in the concrete played a decisive role in affecting the concrete performance. In his experimental study, it was also stated that the compactibility was effective on the concrete strengths and higher dosages of admixtures were needed in roller compacted concrete production [5].

In roller compacted concretes, water-reducing admixtures are used to increase the consistency, decrease the water/cement ratio and increase the concrete strength by easing the dispersion of the cement paste [17]. The increases in compressive strength seen in these concretes with the addition of superplasticizers are due to the uniform distribution of the cement paste, it provides better compaction and reduces the voids in hardened concrete [18]. On the other hand, excessive use of superplasticizers causes the presence of excess water, this water fills the pore volume, and then leaves voids in the hardened RCC matrix by drying, so microcracks develop in the concrete during loading, premature fracture occurs and bending strength reduces [18]. Generally, the use of plasticizers in roller compacted concrete creates a denser concrete structure, decreases the concrete porosity, and increases the thermal conductivity [12].

An important body of knowledge has been added about the use of chemical admixtures in roller compacted concretes, and atypical behaviors in influencing fresh and hardened concrete properties have been explained by presenting plausible mechanisms for binder-admixture interactions [5]. However, more research is needed on this subject, as roller compacted concrete is a newer building material than conventional concrete. Hazaree et al. [4] tested the ten most commonly used chemical admixtures in a typical roller compacted concrete mixture, and observed that each individual mixture provides different benefits and improves different properties of fresh RCC, including changing the setting and finishing properties. They presented a series of recommendations as well as some precautions to be taken in separate use [4].

Nero [19] investigated the effects of the use of superplasticizer and air-entraining admixtures in roller compacted concrete. The use of several different chemical admixtures without evaluating the dosage and quality of chemical admixtures can cause various problems in concrete, some admixtures may not be suitable for use in RCC production, so the components to be used in concrete should be carefully designed and investigated [20]. On the other hand, it should be taken into account that differences between field conditions and laboratory conditions may affect the properties of roller compacted concrete.

In this study, roller compacted concrete with a cement content of 300 kg/m^3 was produced. In production of roller compacted concrete, a third generation high performance mortar and concrete admixture, which provides ultra-high water reduction and long workability in conventional concrete, was used. The chemical admixture was used at the maximum dosage recommended by the manufacturer, as 1% of the cement weight, and the amount of water used in the production of roller compacted concrete was reduced by 10, 20, 30 and 40% compared to the concrete produced without the use of admixtures. With the use of chemical additives, it was aimed to reduce the porosity of RCC and to increase the unit weight and compressive strength values. Unit weight, ultrasonic pulse velocity, dynamic modulus of elasticity, water absorption and compressive strength of the roller compacted concretes were determined.

2. MATERIALS AND METHODS

In roller compacted concrete production, Kırklareli tap water, crushed stone II, crushed stone I, stone dust, natural sand and as the binder CEM I 42.5 R Portland cement were used. The TS EN 1097-6 [21] standard was used to determine the specific gravity of aggregates. The specific gravity of dolomite origin crushed stone II, crushed stone I and stone dust was 2.80, the specific gravity of sand was 2.75 and the specific gravity of cement used was 3.12. Sieve analysis of aggregates was made in accordance with TS EN 933-1 [22] and was given in Table 1. Polycarboxylate-based high range water-reducing chemical admixture was used as 1% of the cement weight and different mixtures were prepared by reducing the amount of water by 10, 20, 30, 40%. The produced mixtures were designed to have a dry consistency as shown in the Figure 1 and a zero slump value.

Figure 1 Consistency of RCC mixture

Table 1 Sieve analysis

	Percentage Passing				
Sieve Size (mm)	**Crushed Stone II (20%)**	**Crushed Stone I (35%)**	**Stone Dust (15%)**	**Natural Sand (30%)**	**Mixture (100%)**
22.5	100.00	100.00	100.00	100.00	100.00
16.0	47.12	100.00	100.00	100.00	86.78
12.5	0.00	94.32	100.00	100.00	73.58
9.5	0.00	79.29	100.00	100.00	69.82
4.0	0.00	9.16	91.73	97.20	49.52
2.0	0.00	0.00	87.45	93.62	45.27
1.0	0.00	0.00	54.44	83.95	34.60
0.5	0.00	0.00	28.21	52.68	20.22
0.25	0.00	0.00	16.06	30.19	11.56
0.125	0.00	0.00	8.03	3.68	2.93
0.075	0.00	0.00	4.32	1.24	1.39

The properties of the ultra-high range water-reducing chemical admixture were given in Table 2.

Table 2 The properties of the chemical admixture [23]

	Property
Appearance/colour	Light brown liquid
Chemical base	Modified polycarboxylate based polymer
Density	1.10±0.02 kg/l at 20°C
pH	3–7
Freezing point	-10°C
Soluble Cl content	Max 0.1%, does not contain Cl (TS EN 934-2)

The material amounts in one cubic meter of roller compacted concrete mixes were given in Table 3. The concrete mix design was made considering the surface dry water-saturated state of the aggregates. The total aggregate mixture consists of 20% crushed stone II, 35% crushed stone I, 15% stone dust and 30% natural sand by weight.

The production of roller compacted concrete specimens was carried out in accordance with the ASTM C1435 [24] standard as shown in the Figure 3. The compaction process was done by using specially produced heads that are compatible with the mold shape. Standard cube specimens were compacted in a monolayer for 15 seconds. Since cold joint formation was encountered in the compaction operations that was performed in more than one layers, compaction in a single layer has been preferred.

Table 3 The material amounts in one cubic meter of roller compacted concrete mixes

Concrete Code	Water Reduction (%)	Water/Cement	Water (kg)	Cement (kg)	Natural Sand (kg)	Stone Dust (kg)	Crushed Stone I (kg)	Crushed Stone II (kg)	Chemical Admixture (kg)
K0	0	0,34	102	300	661	337	785	449	-
K10	10	0,30	88,8	300	670	341	795	454	3
K20	20	0,26	78,6	300	678	345	805	460	3
K30	30	0,23	68,4	300	686	349	815	466	3
K40	40	0,19	58,2	300	695	354	825	472	3

When calculating the percentage of compactibility in the specimens, firstly, cube molds of 15 cm×15 cm×15 cm were filled with RCC mixture up to the upper level, compacted for 15 seconds after leveling, and the gap depth formed at the end of compaction was measured from the middle points of the four edges of the mold. After measuring from four points, the arithmetic averages of these values were taken, and the percentage of compactibility of the RCC specimen was determined by proportioning the determined average value to the inner edge length of the cube mold. The percentage of compactibility has been calculated by considering the Figure 2 and Equation (1) given below, assuming that it can give information about the consistency of the RCC mixtures produced using a vibratory hammer.

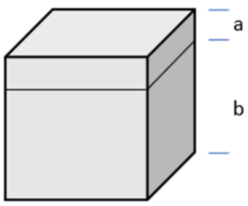

Figure 2 Measured lengths

$$S = \frac{a \times 100}{(a+b)} \tag{1}$$

S= Percentage of compactibility (%)

a= Compaction (mm)

b= Height of the compracted specimen after the mold is filled and leveled (mm)

Figure 3 RCC production

RCC specimens shown in Figure 4 were demolded one day after the production and kept in the curing pool in lime-saturated water until the testing time.

Figure 4 RCC specimens

In determining the compressive strength of roller compacted concretes, 3 and 28-day specimens were tested according to the TS EN 12390-3 [25] standard. Three specimens were tested for each experimental group and average values were determined. The loading rate was taken as 0.602 MPa/s.

Total water absorption percentages of roller compacted concrete specimens at the age of 28 days were determined according to EN 772-11 [26] standard. The weights of the roller compacted concrete specimens, which were dried in a drying-oven for 48 hours and reached a constant weight, were recorded, then these specimens were kept in water for 24 hours and water absorption percentages were calculated.

Ultrasonic pulse velocity of specimens at the age of 28 days were measured in accordance with ASTM C597 [27] standard and dynamic modulus of elasticity of RCC were determined. Proceq brand Pundit PL-200 ultrasonic test device was used to obtain ultrasonic pulse velocity and dynamic modulus of elasticity. For these experiments, 28-d cube RCC specimens with a size of 15 cm×15 cm×15 cm were used. While presenting the experimental findings, three specimens from each series were tested and average values were given.

3. RESULTS AND DISCUSSION

Average compactibility percentages of roller compacted concrete specimens were given in Table 4. As the amount of water was reduced up to 30%, the compactibility percentage decreased in roller compacted concrete, while the compactibility percentage increased slightly when the reduction of water was changed from 30% to 40%. The compactibility percentage decreased by 8.21%, 29.67%, 50.54% and 46.19% in the K10, K20, K30 and K40 specimens, respectively, compared to the reference specimen.

Table 4 Compactibility percentages

Concrete Code	Compactibility Percentage (%)
K0	10.11
K10	9.28
K20	7.11
K30	5.00
K40	5.44

The 3 and 28-day compressive strengths of standard cube RCC specimens were given in Table 5.

Table 5 Compressive strengths (MPa)

Concrete Code	3-d	28-d
K0	26.8	29.9
K10	33.3	39.8
K20	25.5	31.6
K30	13.6	21.6
K40	11.3	12.6

When the 3-d concrete compressive strengths were examined, it was seen that the optimum design was K10 mixture. It can be expected that the compressive strength of concrete will increase as the water/cement ratio decreases, but roller compacted concretes are mixtures with a rather dry consistency compared to normal concrete, and the slump value of the produced concretes was zero. Reducing the mixing water too much makes dissolution of chemical admixture difficult and prevents the distribution of plasticizer properly in concrete, and the chemical admixture cannot show the expected performance when the amount of mixing water reduced more than a certain value.

While the admixture used can provide water reduction of up to 30% in conventional concrete, it has been observed that water reduction of more than 10% in roller compacted concrete causes a decrease in compressive strength due to problems in workability and compaction. A 10% reduction in water content, which makes a decrease in water/binder ratio, provided a 24% increase in compressive strength compared to the reference concrete in 3-d specimens. Reducing the mixing water by 20% caused a 5% decrease in the 3-d compressive strength, while reducing the water amount by 30% decreased the compressive strength by 49%. Reducing the mixing water by 40% in the roller compacted concrete mixture caused the 3-d concrete compressive strength to be 58% lower than the reference concrete.

When the 28-day concrete compressive strengths were examined, it was seen that the highest values were obtained with the K10 specimen. By reducing the mixing water by 10%, the 28-d compressive strength has increased by 33%

compared to the reference concrete. When the amount of water was reduced by 20%, this increase was limited to 6%, while further reduction of the amount of water caused a decrement in the compressive strength of concrete. When the water amount was reduced by 30%, the 28-d compressive strength of the concrete decreased by 28%, and when the water amount was reduced by 40%, the strength decreased by 58%. Here, the hyper plasticizer admixture, which was suitable for conventional concrete production, did not work effectively in RCC mixtures where the amount of water was very low, compressive strengths decreased in contrast to the expected outcome related to the decrease in water/binder ratio. Even if the ultra-high range water reducer was used, reducing the amount of water by more than 10% adversely affected the mechanical properties. After compaction process, the amount of voids in concrete and the porosity of RCC can also be effective in obtaining this result.

Adamu et al. stated that the use of 1% chemical additives in RCC production increased the compressive strength value [18]. Nero and Haldenbilen determined that the compressive strength values of the specimens they produced using 1% chemical additives increased by 4% [20]. In addition, Alnusair et al. determined that the use of 0.75% chemical additives increased the compressive strength value by 24% [28].

The water absorption percentages of the roller compacted concrete specimens were given in Table 6. Among the RCC specimens, the K10 specimen had the lowest water absorption percentage.

Table 6 Water absorption percentages

Concrete Code	Water Absorption (%)
K0	7.58
K10	6.22
K20	7.79
K30	8.54
K40	7.76

The unit weights of roller compacted concretes were given in Table 7. When the dry unit weights were compared, it was seen that the densest structure was obtained with the K10 specimen, and the porosity was the lowest in this specimen. Dry unit weights were consistent with compressive strengths. It was observed that the compressive strengths increased as the compactness of the material increased. The saturated unit weight was affected by the water absorption percentage of the material.

Table 7 Unit weights

Concrete Code	Dry Unit Weight (g/cm^3)	Saturated Unit Weight (g/cm^3)
K0	2.39	2.57
K10	2.45	2.60
K20	2.42	2.61
K30	2.38	2.58
K40	2.34	2.52

Ultrasonic pulse velocity and dynamic modulus of elasticity of roller compacted concretes at the age of 28 days were given in Table 8. As the ultrasonic pulse velocity increased, the dynamic modulus of elasticity and compressive strength increased, the highest values were obtained with the K10 specimen.

Table 8 Ultrasonic pulse velocity and dynamic modulus of elasticity

Concrete Code	Ultrasonic Pulse Velocity (km/s)	Dynamic Modulus of Elasticity (GPa)
K0	4.44	30.34
K10	4.60	32.05
K20	4.02	24.30
K30	3.95	23.30
K40	3.41	19.68

When the ultrasonic pulse velocities were examined, there was a 3.60% increase in the K10 specimen, a 9.46% decrease in the K20 specimen, an 11.04% decrease in the K30 specimen, and a 23.20% decrease in the K40 specimen, compared to the reference.

According to the ASTM C 597 [27] standard, if the ultrasonic pulse velocity is between 3.5 and 4.5 km/s, the concrete quality is considered as good. Since K0, K20 and K30 specimens met this condition, it can be said that these concretes' quality was good. While the K10 specimen was in very good condition in terms of concrete quality, it was observed that the concrete quality in the K40 specimen was insufficient compared to other concretes. In K40 specimen, excessive reduction in water/binder ratio and the uneven distribution of the cement paste resulted in workability problems, weakening of the aggregate-matrix interface, and consequently affecting the physical and mechanical properties adversely.

When the dynamic modulus of elasticity values were examined, it was seen that there is a 5.64% increase in the K10 specimen, a 19.91% decrease in the K20 specimen, a 23.20% decrease in the K30 specimen, and a 35.14% decrease in the K40 specimen compared to the reference.

The relationships between ultrasonic pulse velocity (UPV)-concrete compressive strength and UPV-dynamic modulus of elasticity were shown in Figure 5. The results obtained were affected by the void structure of concrete. As the amount of voids in the RCC increased, the ultrasonic pulse velocity decreased, and the compressive strength and dynamic modulus of elasticity decreased.

Measurement of ultrasonic pulse velocity is a non-destructive test method and can be affected by parameters such as the measurement point and direction of compaction in RCCs. Ultrasonic pulse velocity is directly related to the amount of voids in the concrete, since the compressive strength is also affected by the porosity, it is useful to determine the UPV in order to have an idea about the compressive strength without damaging the concrete. A close linear relationship was obtained between the ultrasonic pulse velocity and the concrete compressive strength, as expected. In addition, there was a strong linear correlation between ultrasonic pulse velocity and dynamic modulus of elasticity.

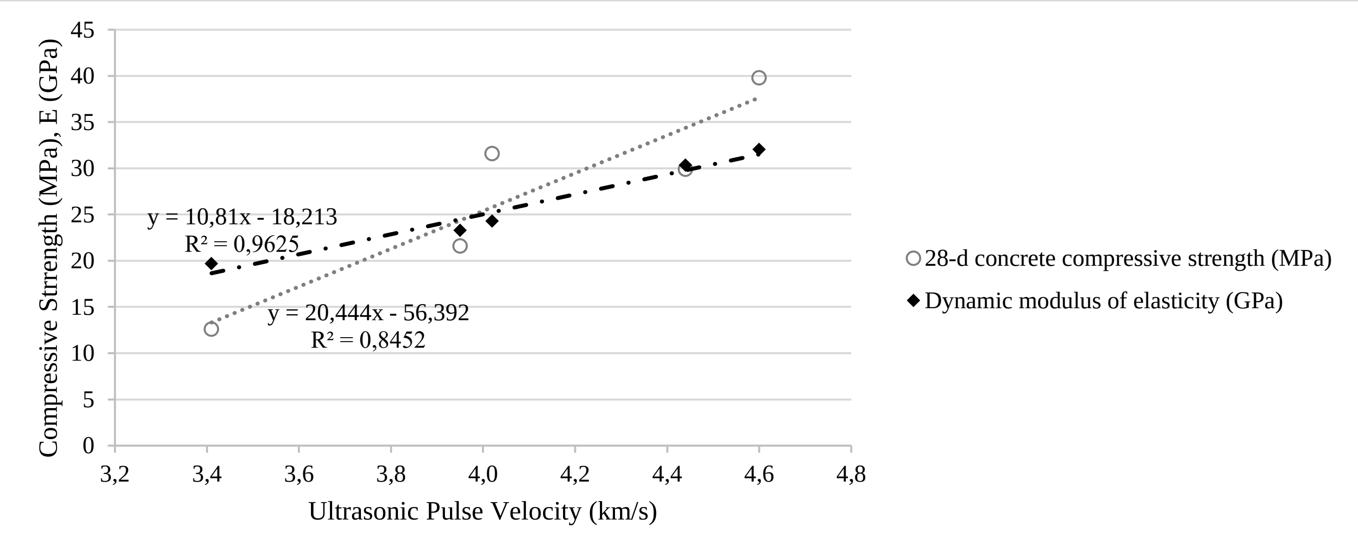

Figure 5 Ultrasonic pulse velocity (UPV), concrete compressive strength and dynamic modulus of elasticity

4. CONCLUSION

Based on the data from the experimental study, the following conclusions were drawn:

When the ultra-high range water reducing admixture was used in RCC as 1% of the weight of cement, the best results were obtained in terms of concrete compressive strength at the ages of 3 and 28 days by reducing the amount of water by 10%.

When the water/cement ratio was reduced below a certain value in roller compacted concrete, the expected increase in compressive strength does not occur due to problems in compactibility and workability.

At earlier ages, with the reduction of the amount of mixing water in the concrete by more than 10%, the compressive strength of the concrete produced by using chemical admixtures was lower than the reference specimen. Based on this result, it was thought that chemical admixtures should dissolve in water and disperse homogeneously in the concrete in order to work effectively. In roller compacted concrete, a much drier mixture is obtained than conventional concrete. When the amount of water in the RCC mixture is reduced too much, the admixture used cannot have a positive effect on the workability due to the inability to disperse in the concrete, negatively affecting the mechanical properties.

In RCC production, by using a modified polycarboxylate-based plasticizer at the rate of 1% of the cement weight, optimum values were obtained in terms of unit weight, compressive strength, water absorption, ultrasonic pulse velocity and dynamic modulus of elasticity by reducing the amount of mixing water by 10%. In this mixture, the porosity was the lowest, the concrete quality was at the best level and higher compressive strength values were obtained compared to the other series.

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Authors' Contribution

The authors contributed equally to the study.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

REFERENCES

[1] Ş. Yazıcı, "Silindirle Sıkıştırılmış Beton (SSB)", 2008. Retrieved from https://www.imo.org.tr/resimler/ekutuphane/pdf/14954.pdf Access Date: 30.06.2021.

[2] İ. Kılıç and S. G. Gök, "Silindirle Sıkıştırılmış Betonlarda Su/Çimento Oranının Etkileri", Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi, vol. 10, no. 1, pp. 73–84, Jun. 2021.

[3] C. Chhorn and S. W. Lee, "Consistency control of roller-compacted concrete for pavement", KSCE J Civ Eng, vol. 21, pp. 1757–1763, 2017.

[4] C. V. Hazaree, H., Ceylan, P. Taylor, K. Gopalakrishnan, K. Wang and F. Bektas, "Use of Chemical Admixtures in Roller-Compacted Concrete for Pavements", InTrans Project Reports. 57, 2013. Retrieved from https://lib.dr.iastate.edu/intrans_reports/57 Access Date: 27.06.2021

[5] C. V. Hazaree, "Workability and strength attributes of RCC: Effects of different chemical admixtures and resulting paste", Graduate Theses and Dissertations, 11250, 2010. Retrieved from https://lib.dr.iastate.edu/etd/11250 Access Date: 01.06.2021

[6] D. Harrington, F. Abdo, W. Adaska, C. V.

Hazaree, H. Ceylan and F. Bektas, "Guide for roller-compacted concrete pavements", 2010.

[7] A. Modarres and Z. Hosseini, "Mechanical properties of roller compacted concrete containing rice husk ash with original and recycled asphalt pavement material", Materials and Design, vol. 64, pp. 227–236, 2014.

[8] E. Şengün, M. A. Aykutlu and İ. Ö. Yaman, "Silindirle Sıkıştırılmış Beton Yollar Üzerine Güncel Bir Tarama - Bölüm 1: Özellikleri ve Karışım Tasarımı", Çimento ve Beton Dünyası, vol. 120, no. Kasım-Aralık 2017, pp. 93–114, 2017.

[9] TÇMB, "Silindirle Sıkıştırılmış Beton Yollar Teknik Şartnamesi", Ankara, 2018.

[10] E. Yetim and D. Yılmaz, "Beton Yollar ve Silindirle Sıkıştırılmış Betonun Türkiye'deki Yeni Uygulama Alanı", 2019. Retrieved from https://webdosya.csb.gov.tr/db/yfk/icerikler/makale---beton-yollar-9-eylul-2019-20191220130448.pdf Access Date: 03.06.2021.

[11] L. Shen, Q. Li, W. Ge and S. Xu, "The mechanical property and frost resistance of roller compacted concrete by mixing silica fume and limestone powder: Experimental study", Construction and Building Materials, vol. 239, 117882, 2020.

[12] M. Hashemi, P. Shafigh, I. Asadi, A. Mahpour and A. Samadian, "The effect of superplasticizer admixture on the engineering characteristics of roller-compacted concrete pavement", International Journal of Pavement Engineering, pp. 1–16, 2020.

[13] KGM, "Beton Yollar Teknik Şartnamesi", Karayolları Genel Müdürlüğü, Ankara, 2016.

[14] TS EN 934-1, "Kimyasal katkılar - Beton, harç ve şerbet için - Bölüm 1: Katkılara ait ortak gerekler", TSE, Ankara, 2010.

[15] TS EN 934-2+A1, "Kimyasal katkılar - Beton, harç ve şerbet için - Bölüm 2: Beton kimyasal katkıları - Tarifler, gerekler, uygunluk, işaretleme ve etiketleme", TSE, Ankara, 2013.

[16] Y. Engin, İ. Gökalp, E. Önkol, H. Ağaç and H. Ekim, "Türkiye'de Silindirle Sıkıştırılmış Beton Yol Uygulamaları", Hazır Beton, Eylül-Ekim 2019, pp. 69–75, 2019.

[17] M. Adamu, B. S. Mohammed and N. Shafiq, "Effect of Polycarboxylate Superplasticizer Dosage on the Mechanical Performance of Roller Compacted Rubbercrete for Pavement Applications", Journal of Engineering and Applied Sciences, 12(20), pp. 5253–5260, 2017. DOI: 10.36478/jeasci.2017.5253.5260.

[18] M. Adamu, B. S. Mohammed and N. Shafiq, "Evaluating the effect of superplasticizer on the properties of roller compacted concrete using response surface methodology", ARPN Journal of Engineering and Applied Sciences, vol. 12, no. 21, pp. 6206–6215, 2017.

[19] M. A. Nero, "Silindirle Sıkıştırılmış Betonlar İçin Kimyasal Katkıların Etkilerinin Belirlenmesi", Yüksek Lisans Tezi, Pamukkale Üniversitesi, Denizli, Türkiye, 2019.

[20] M. A. Nero and S. Haldenbilen, "Determining the Effects of Chemical Admixtures on Roller Compacted Concrete (RCC)", American Journal of Engineering and Technology Management, vol. 5, no. 1, pp. 27–34, 2020.

[21] TS EN 1097-6, "Agregaların mekanik ve fiziksel özellikleri için deneyler - Bölüm 6: Tane yoğunluğu ve su emme oranının tayini", Türk Standartları Enstitüsü, Ankara, 2013.

[22] TS EN 933-1, "Agregaların geometrik özellikleri için deneyler-bölüm 1: tane büyüklüğü dağılımının tayini-eleme yöntemi", Türk Standartları Enstitüsü, Ankara, 2012.

[23] Url-1 <https://heris.com.tr/Resimler/2d9557f65cSika%20Viscocrete%20SF%2018%2020072201%20TR.pdf> Retrieved on 03.07.2021.

[24] ASTM C1435/1435M-20, “Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer”, American Society for Testing and Materials, ASTM International, USA, 2020.

[25] TS EN 12390-3, "Beton - Sertleşmiş beton deneyleri-bölüm 3: sertleşmiş beton deney numunelerinde basınç dayanımının tayini", Türk Standartları Enstitüsü, 2019.

[26] EN 772-11, "Methods of Test for Masonry Units Part 11: Determination of water absorption of aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units", BSI Stand. Publ., London, UK, 2011.

[27] ASTM C597-16, "Standard Test Method for Pulse Velocity Through Concrete", ASTM International, West Conshohocken, PA, 2016.

[28] A. H. Alnusair, H. Y. Katman, M. R. Ibrahim, N. A. Rahman, “The Effect of Superplasticizer on Performance of Roller Compacted Concrete Pavement Containing High Volume Fly Ash”, International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 4, ISSN: 2277-3878, November 2019.