EXAMINATION OF CONCRETE MIXTURES – PART I MATERIAL PROPERTIES

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Summary: *Concrete mixtures are made, or prepared with aggregates, binders and water, and in some concrete chemical additives are used to improve the properties of concrete mixtures. The paper presents the results of the properties testing of crushed stone aggregates, cement (CEM II / A-M (S-L) 42,5 R), water for concrete production, concrete admixtures (SIKA VISCOCRETE 3070 and SIKA AER). The composition of concrete mixtures is shown in the second part of the paper, because due to the large number of results, the work is divided into two parts. According to test results it can be concluded that tested materials satisfy properties described by SRPS standars.*

Keywords: *aggregate, cement, chemical additive, water*

1. INTRODUCTION

Preparation of concrete mixtures is complex because it requires a considerable time consuming in the analysis of materials used for the preparation. Concrete mixtures are made mainly from aggregates, cement and water, but in some concrete mixtures depending on where they are used later, chemical admixtures are added to improve the properties of concrete. Depending on the literature review, it is found that all works first show the properties of the material, and then give the results of the concrete mixtures testing. The paper [1] gives an overview of the properties of the material before the preparation of concrete mixtures. The limits are set based on the defined standards used

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for this scientific area. After the analysis, it was concluded that the aggregate can be used for the concrete pavement of certain strength and that it fulfills the conditions that are prescribed by the SRPS standards.
Similar concepts have also been noted in other authors [2-4] where an aggregate test is given, and then the physical-mechanical properties of cement and the examination of chemical additives for the preparation of concrete mixtures. Concrete mixtures have been analyzed mainly for concrete pavements and for structural elements such as bridges and residential-business buildings. Material quality testing procedures are an important parameter for concrete mixtures preparing, as it is observed whether the test material meets the requirements of the standard, or whether it is within the limits prescribed by the standard for the application of the structural element.
This paper presents an examination of the properties of aggregates, but crushed stone aggregates (fractions 0/4, 4/8 and 8/16 mm), cement (LaFarge CEM II / A-M (S-L) 42,5 R), chemical additives (SIKA VISCOCRETE 3070 and SIKA AER) and water.

2. EXPERIMENTAL RESEARCH

Concrete was produced on the basis of pre-determined recipes, that is, on the basis of the concrete mixture project, which should contain all the adopted quantities of component materials. The component materials of concrete were: aggregate (crushed stone), cement (CEM II A-M (S-L) 42.5R), chemical additives (Sika ViscoCrete 3070, Sika-Aer) and water.

2.1. Aggregate

A crushed stone aggregate for the preparation of a concrete mixture was used for aggregate testing. The aggregate was sampled from the quarry "Drenovački KIK". The following tests were carried out for the aggregate:

- Grain size distibution of aggregate (SRPS B.B8.029), and at the same time a quality codition for granulometric composition is determined according to standards SRPS B.B2.010 and SRPS B.B3.100;
- Fine modulus for a small aggregate (SRPS B.B2.010);
- The content of tiny aggregate particles (SRPS B.B8.036);
- Aggregate grain shape (SRPS B.B8.049);
- Density and water absorption (SRPS B.B8.031);
- Resistence to crushing and wear – Los Angeles method (SRPS B.B8.045).

During the test for some methods, not all three test fractions were used, because standard specifies which fractions can be used for testing. Grain size distibution of aggregate was done for all of three aggregate fractions, while for the fine modulus for a small aggregate was used only the first fraction and it has to be fullfiled the condition of minimum 2.3 to maximum 3.6 for modulus value. If the test result does not meet the specified conditions, it is considered that the aggregate is not suitable for the preparation of concrete mixtures which require higher physical and mechanical characteristics of hardened concrete. Three aggregate fractions were used for testing of the content of tiny aggregate particles,

aggregate grain shape and density. Resistence to crushing, the Los Angeles method, was done with fractions of 8/16 and 16/22 mm.

2.2. Cement

For the concrete preparation cement LaFarge CEM II / A-M (S-L) 42,5 R was used from the Beočin cement plant. The material was sampled in certain quantities, on the basis of which the following tests were carried out: Fineness (SRPS EN 196-6), Standard consistence (SRPS EN 196-3), Cement setting times, ie beginning and end of binding (SRPS EN 196-3), Soundness (SRPS EN 196-3) and Flexural and compressive strength at 2 and 28 days (SRPS EN 196-1). The required values of the results were prescribed by the defined standards depending on the type of test which was done for the material.

2.3. Water

For the preparation of concrete mixtures, water from the water supply system is mainly used because it is controlled and fulfills the conditions necessary for the use of concrete. In this paper, following water tests were done: pH value, chloride content, sulphate content, sulphide content, nitrate content, phosphate content, bicarbonate content and the difference in the setting time between the cement paste with the water being tested and the distilled water, ie the beginning and the end of binding. The entire listed tests were done according to standard SRPS U.M1.058.

2.4. Chemical additives

The chemical additives used for testing and subsequent concrete preparation were as follows: Sika Viscocrete 3070 and Sika Aer.

2.4.1. Sika Viscocrete 3070

For the Sika Viscococrete testing purposes, the following physical and chemical properties were done: bulk density in liquid state; surface stress, the content of dry matter and pH value. The entire listed tests were done according to standard SRPS U.M1.035.

2.4.2. Sika Aer

The Sika Aer chemical additive was tested according to the same standard for the same physical and mechanical properties as in the previous subsection (2.4.1).

3. RESULTS AND DISCUSSION

3.1 Aggregate

Grain size distibution of aggregate is shown in Figure 1. It was noticed that the aggregate has no undersize and oversize grains and meets all the requirements prescribed by the standard SRPS B.B2.010 and SRPS B.B3.100, i.e. It is within the prescribed limits of the minimum and maximum content of aggregate fractions.

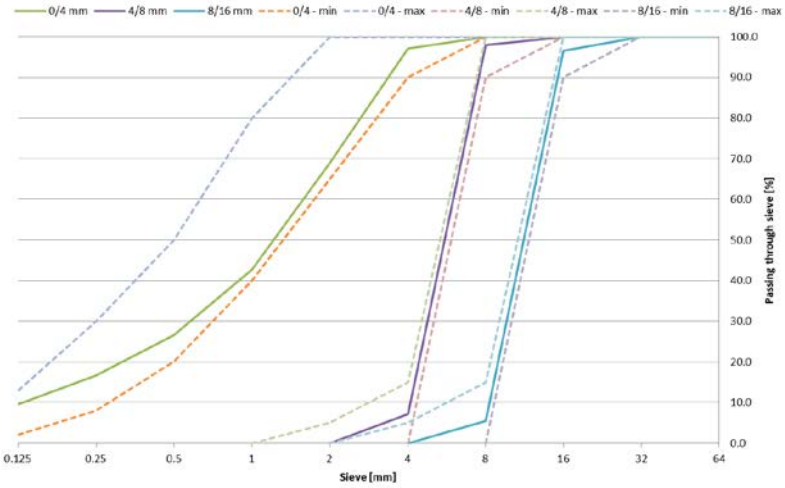

Figure 1 – Grain size distibution of aggregate

Fine modulus for a small aggregate is shown in Table 1. It is noted that the fine modulus is within the prescribed limits defined by the standard.

Table 1 – Grading modulus of fine aggregate

Test method	Fine aggregate/ Fraction	Grading modulus of fine aggregate	
		Achieved	Required
SRPS B.B2.010	0/4 mm	3.39	min 2.3 – max 3.6

The testing of the content of fine particles of each fraction after test sieves is shown in Table 2.It can be seen that according to the standard they have maximum limits of fine particles that may contain certain fraction.

Table 2 – Content of small particles

Test method	Fraction [mm]	Content of small particles < 0.09 mm, %	
		Achieved	Required
SRPS B.B8.036	0/4	9.8	max 10%
	4/8	0.8	max 1%
	8/16	0.7	max 1%

Table 3 – Particle shape (volumetric coeficient)

Test method	Fraction [mm]	Content of small particles < 0.09 mm, %	
		Achieved	Required
SRPS B.B8.049	0/4	-	-
	4/8	0.21	≥0.15
	8/16	0.25	≥0.15

The aggregate grain shape was tested according to the abovementioned standard SRPS B.B8.049. Based on the standards and carried tests shown in Table 3, it was determined that the grain shape fulfills the prescribed conditions. The bulk density and water absorption of the aggregate are shown in Table 4. After the tests, the results of bulk density of the crushed stone aggregate is within the defined limits prescribed by a certain standard, while the absorption of water is low compared to natural aggregates.

Table 4 – Bulk density and water absorption

Test method	Fraction [mm]	Bulk density [kg/m^3]		Water absorption [%]	
		Achieved	Required	Achieved	Required
SRPS B.B8.031	0/4	2740	2000-3000	0.86	-
	4/8	2810	2000-3000	0.85	-
	8/16	2800	2000-3000	0.61	-

In addition to the above tests, resistance to crushing and wearing has also been made. Since these are mixtures that are used for roads and long span constructions, the anti-crushing and wear coefficient must be less than or equal to 16. After the conducted research, it was found that the crushed aggregate fulfills the conditions given in standard (Table 5).

Table 5 – Resistance to crushing and abrasion – Los Angeles

Test method	Fraction [mm]	Content of small particles < 0.09 mm, %	
		Achieved	Required
SRPS B.B8.045	8/16, 16/22	16.0	≤16.0

3.2 Cement

For the concrete preparation one type of cement was used and is from the Beočin cement plant. The results of the physical-mechanical properties of the cement test are shown in Table 6. By comparing the obtained and required results, it is understood that the test material, i.e. the binder, fullfils the conditions and standards on the basis of which the test was done.

Table 6 – Testing results of cement

Type of test	Test method	Results	
		Achieved	Requried
Fineness (on sieve) [%]	SRPS EN 196-6	0.875	≤10
Standard consistency [%]	SRPS EN	27.20	-

		196-3		
Setting time [min]	start after	SRPS EN	160	≥50
	finish after	196-3	200	≤600
Volume stability	cakes	SRPS EN	stability	stability
	on Le Chatelier's rings [mm]	196-3	0.00	≤10
Flexural strength [MPa]	on 2 days	SRPS EN	5.4	-
	on 28 days	196-1	9.4	-
Compressive strength [MPa]	on 2 days	SRPS EN	25.8	≥18.0
	on 28 days	196-1	50.7	≥40

3.3 Water

Water was tested using the SRPS U.M1.058 standard and Table 7 gives the values of the water that can be used for the preparation of concrete mixtures.

Table 7 – Testing results of water

Properties	Achieved	Requried
pH value	8.48	4.5 – 9.5
Chloride content (Cl^-) [mg/l]	7.8	300
Sulfate content (SO_4^{2-}) [mg/l]	15.6	2700
Sulfide content (S^{2-}) [mg/l]	0.0	-
Nitrate content (NO_3^-) [mg/l]	400.0	500
Phosphate content (PO_4^{3-}) [mg/l]	-	100
Bicarbonate content (alkalni $NaHCO_3$) [mg/l]	280.6	1000
Potassium-permanganate consumption ($KMnO_4$) [mg/l]	15.2	200
The content of the soluble matter as the residue of the evaporated water [mg/l]	242.0	5000
The content of insoluble matter as the difference between the residue of the vapor of the undrained and drained water [mg/l]	-	2000
The difference in the setting time between the cement paste with water being tested and distilled water: - begining - endj	 0 0	 30 30

3.4 Hemijski dodaci

3.4.1 Sika Viscocrete 3070

An analysis of chemical additive Sika Viscocrete 3070 tests has been carried out, on the basis of which the test results are shown in Table 8. The results of the test have shown that the results are within the limits prescribed by the SRPS U.M1.035 criteria, on the basis of which this material is suitable and can be used for making concrete mixtures.

Table 8 – Testing results of Sika Viscocrete 3070

Parameter	Criterion SRPS U.M1.035	Requried
Bulk density in liquid state	1.090±0.05	1.080 g/cm^3
Surface stress: - water - water-cement solution 0.85g add./30 ml water	 - -	 72.73x10^{-5} N/cm 59.80x10^{-5} N/cm
Content of dry matter	27.22±0.43	26.84%
pH value: - water - water solution 0.85g add./30 ml water	 - 5.26±0.5	 7.20 5.10
Chlorine content Cl^- ion	0.00±0.00	0.00%

3.4.2 Sika Aer

An aerated test was performed for concrete mixtures. The results of the tests are presented in Table 9, which shows that the results are within the limits prescribed by the standard and that this aerator is suitable for the preparation of the concrete mixture.

Table 9 – Testing results of Sika Aer

Parameter	Criterion SRPS U.M1.035	Requried
Bulk density in liquid state	-	1.010 g/cm^3
Surface stress: - water - water-cement solution 0.85g add./30 ml water	 - -	 72.73x10^{-5} N/cm 66.41x10^{-5} N/cm
Content of dry matter	-	5.18
pH value: - water - water solution 0.85g add./30 ml water	 - -	 6.90 5.77
Chlorine content Cl^- ion	0.00±0.00	0.00%

4 CONCLUSION

After analyzing the graphical and tabular results shown in this paper, the following can be concluded:

- the all aggregate tests included in this paper have been satisfied by the SRPS standards and can be applied for the construction of concrete pavements as well as for the structural elements of civil engineering;
- after examination of the physical-mechanical properties of cement, it was found that it is a material that also fullfils all the criteria and regulations that are required according to standards;

- the water used for the preparation of the concrete mixtures is correct and based on the paper tests it has been proven that the drinking water can be used for the preparation of concrete. It is only necessary to check water from wells or some other sources in order to determine its composition and properties;
- the tested chemical additives also showed satisfactory criteria as well as any other components used for the preparation of concrete mixtures.

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REFERENCES

[1] Šešlija M., Radović N., Rašeta A., Starčev-Ćurčin A., Kukaras D.: Physicomechanical properties of concrete mixtures for construction of pavements at bus stations, Građevinar, 70/2, pp. 121-132, 2018
[2] Suelyman Gokce H., Andic-Cakir O.> Bleeding characteristics of high consistency heavyweight concrete mixtures, Construction and Building Materials, 194, pp. 153-160, 2019
[3] Dastgerdi Shafiei A., Peterman R., Riding K., Beck T: Effect of concrete mixture components, proportioning and compressive strength on fracture parameters, Construction and Building Materials, 206, pp. 179-192, 2019
[4] Jiao D., Shi C., Yuan Q., An X., Liu Y.: Mixture design of concrete using simplex centroid design method, Cement and Concrete Composites, 89, pp. 76-88, 2018
[5] SRPS B.B8.029 – *Crushed aggregate - Test for dry sieve analysis*, Institute for Standardization of Serbia, Belgrade, 1982
[6] SRPS B.B2.010 – *Aggregate for concrete - Technical requirements*, Institute for Standardization of Serbia, Belgrade, 1986
[7] SRPS B.B3.100 – *Crushed aggregates for concrete and asphalt*, Institute for Standardization of Serbia, Belgrade, 1983
[8] SRPS B.B8.036 – *Crushed aggregate - Determination of fine particles with the wet sieve analysis*, Institute for Standardization of Serbia, Belgrade, 1982
[9] SRPS B.B8.049 – *Mineral aggregate - Determination of volumetric coefficient*, Institute for Standardization of Serbia, Belgrade, 1984
[10] SRPS B.B8.031 – *Crushed aggregate - Determination of particle density and water absorption*, Institute for Standardization of Serbia, Belgrade, 1982
[11] SRPS B.B8.045 – *Testing of natural rock - Testing of natural and crushed aggregate rock by machine "los angeles"*, Institute for Standardization of Serbia, Belgrade, 1978
[12] SRPS EN 196-6 – *Methods of testing cement – Part 6: Determination of fineness*, Institute for Standardization of Serbia, Belgrade, 2011

[13] SRPS EN 196-3 – *Methods of testing cement – Part 3: Determination of setting times and soundess*, Institute for Standardization of Serbia, Belgrade, 2010
[14] SRPS EN 196-1 – *Methods of testing cement – Part 1: Determination of strength*, Institute for Standardization of Serbia, Belgrade, 2008
[15] SRPS U.M1.058 – *Concrete - Water for making concrete - Technical requirements and testing methods*, Institute for Standardization of Serbia, Belgrade, 1985
[16] SRPS U.M1.035 – *Concrete - Admixtures for concrete - Quality requirements and testing*, Institute for Standardization of Serbia, Belgrade, 1996

ИСПИТИВАЊЕ БЕТОНСКИХ МЕШАВИНА – ДЕО I СВОЈСТВА МАТЕРИЈАЛА

Резиме: *Бетонске мешавине се справљају помоћу агрегата, везива и воде, а могу се користити и хемијски додаци који поспешују својства бетонских мешавина. У раду су приказани резултати испитивања својстава дробљеног каменог агрегата, цемента (CEM II / A-M (S-L) 42,5 R), воде за справљање бетона и додатака у бетону (Sika Viscocrete 3070 и Sika Aer). Због великог броја резултата, рад је подељен у два дела. Састав бетонских мешавина је приказан у другом делу рада. У овом првом раду, на основу резултата испитивања, утврђено је да употребљени материјали задовољавају услове који су прописани у СРПС стандардима.*

Кључне речи: *агрегат, цемент, хемијски додатак, вода*