EXAMINATION OF CONCRETE MIXTURES FOR PRODUCTION OF CONCRETE PAVEMENT

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Summary: *Rigid pavement is represented by concrete pavement. In this paper, for the analysis, three mixtures tests were carried out for preparation of concrete mixtures, and then the tests of compressive strength and density were performed. The test was done at 7 and 28 days, where the samples were cured in laboratory conditions. The mixtures differ by type and amount of cement, aggregates, superplasticizers, aerators and water-cement factors. Based on the test results, for all of three mixtures, the compressive strengths at 28 days are greater than or equal to 40MPa, and it can be concluded that all mixtures fulfill the requirement for production of concrete pavement.*

Keywords: *concrete pavement, mixtures, comressive strength*

1. INTRODUCTION

Since the old Romans [1], the development of concrete pavements began. In that period, the pavement structures consisted of a crushed stone material layer bounded with a natural hydraulic binder (volcanic ash from Pocuoli near Naples) [2]. With the construction of the first cement macadam, in 1888 in Wrocław, a modern era of concrete pavement has started [3]. However, the first classic concrete pavement was built later, in 1891 in Belfauntn, USA, using only modest craft technologies [4]. In Germany in 1930 the first machine-made roads appeared [5]. In Serbia, the beginning of the construction of concrete pavements is linked to the period before the First World War and

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immediately after the Second World War, but soon the construction of concrete pavements on the Serbian roads completely stopped [1]. Concrete pavements are not widely represented in our country, but they are widely used in developed countries, mainly in the USA and in the countries of Europe (Austria, Germany, Belgium, Czech Republic, etc.) [1]. Concrete pavements are performed only in special places, such as toll booths on highways, petrol stations and bus stops. For example, in the Czech Republic, about 50% of the highways are made of concrete [3]. The advantages of concrete in relation to asphalt pavements are multiple. The rigidity and compressive strength of the concrete influence the distribution of the load over a relatively wide surface, so that the load on the subbase is low and the layers below the concrete slab have smaller dimensions compared to the layers of asphalt pavement constructions [6]. Physical and mechanical properties cause less need for maintenance, repair and reconstruction of concrete pavements in relation to asphalt pavements. Namely, in the case of concrete pavements there are no deformations in the form of rutting caused by the movement of the vehicle, since the rigid pavement construction reduces the deformation of the pavement, which ultimately affects the reduction in fuel consumption of the vehicle [7].
An overview of the concrete mixtures testing is given in this paper, means the laboratory testing of concrete compressive strength at 7 and 28 days. Three different types of concrete mixtures, which differ in aggregate, cement and chemical additives, were used for the test.

2. EXPERIMENTAL RESEARCH

Based on the concrete mixture project, which should contain all the adopted quantities of component materials, concrete was produced on the basis of pre-determined recipes. The concrete component materials were: aggregate (natural and crushed), cement (CEM I 42.5R, CEM II A-M (S-L) 42.5R), chemical additives (Sika ViscoCrete 3070, Sik-Antigelo, Sika ViscoCrete 1020X) and water.

2.1 Aggregate

For the research proposes, crushed stone from the quarry "Rakovac" and natural gravel from the Drina river were used. After delivery of the aggregate, dry screening was carried out, and representative sample was obtained by the method of quartering [8]. The line of sieving of natural and crushed aggregates is shown in Figure 1. It can be noticed that there are no submerged and excessive grains for natural gravel and crushed stone aggregate.

2.2 Cement

In the test analysis, two types of cement were used for the binder: CEM I 42.5R and CEM II A-M (S-L) 42.5R (Table 1). The physical and mechanical properties of cement were tested according to the standards: SRPS EN 196-1 [9], SRPS EN 196-3 [10] and SRPS EN 196-6 [11]. Based on the obtained results, it was concluded that both types of cement satisfied the prescribed physical-mechanical properties defined in the standard SRPS EN 197-1 [12]. Also, compressive strength and flexural strength were tested on cement samples. For each mechanical property, three samples were examined, and the mean value of the tested samples after a certain age are shown in Table 2.

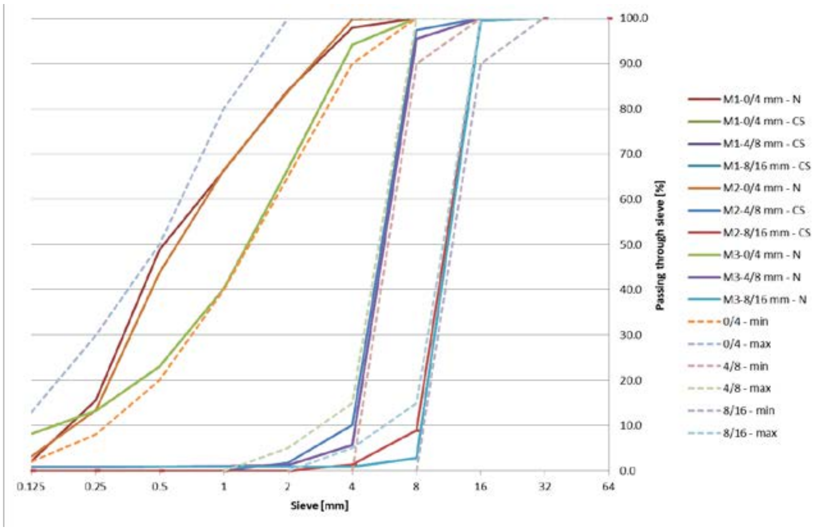

Figure 1 – Granulometric composition of natural (N) and crushed aggregates (CS)

Table 1 – Physical and chemical properties of cement

Type of testing		CEM I 42.5R	CEM II A-M (S-L) 42.5R
Fineness (on sieve) [%]		0.30	0.40
Standard consistency [%]		28.4	28.2
Setting time	start after [min]	180	125
	finish after [min]	240	185
Volume stability (Le Chatelier) [mm]		0	0
Specific surface [cm^2/g]		4100	4100
Specific mass [g/cm^3]		3.14	3.07
SiO_2 [%]		20.76	20.65
Al_2O_3 [%]		5.87	4.96
Fe_2O_3 [%]		3.22	2.87
CaO [%]		61.22	60.72
MgO [%]		3.01	3.01
SO_3 [%]		3.18	2.84
Na_2O [%]		0.41	0.35
K_2O [%]		0.80	0.71
MnO [%]		0.16	0.17
Loss by ignition [%]		1.31	3.94

Table 2 – Mechanical properties of cement

Type of testing	Sample age [days]			
	CEM I 42.5R		CEM II A-M (S-L) 42.5R	
	2	28	2	28
Compressive strength	29.4	52.3	27.2	51.8
Flexural strength	6.9	8.9	6.1	8.8

2.3 Chemical additives

For concrete mixtures two superplasticizers were used (Sika ViscoCrete 3070 and Sika ViscoCrete 1020X) and aerator (Sik-Antigelo). Addition of the superplasticizer was used for the purpose of improving the embedding and workability of the mixture and reducing the amount of water. Aerators in the concrete structure form fine, uniformly distributed air bubbles.

2.4 Concrete mixtures

For testing three concrete mixtures, which are marked with M1, M2 and M3, were made. During the examination process, two types of cement from the same manufacturer LaFarge were used, while for the aggregate, the combination of natural and crushed stone aggregates was used. In Table 3 the ingredients of all concrete mixtures are shown. During the production of the M1 mixture, only the natural aggregate was used, while the combination of natural and crushed stone aggregates was used for the mixture M2. For the first fraction, a natural aggregate was used, while a crushed stone aggregate from the quarry was used for the second and third fractions. The M3 mixture was made by combining natural and crushed stone aggregates for the first fraction, ie 20% of the natural aggregate and 20% of the crushed aggregate. For other fractions (second and third), a crushed stone aggregate was used.

Table 3 – Quantity of ingredients for 1m^3 of concrete

<table>
<tr><td colspan="2">Mixture ingredients [kg/m^3]</td><td colspan="2">M1</td><td colspan="2">M2</td><td colspan="2">M3</td></tr>
<tr><td colspan="2">Cement</td><td colspan="2">[2)]321</td><td colspan="2">[1)]361</td><td colspan="2">[2)]443</td></tr>
<tr><td rowspan="3">Aggregate</td><td>0/4</td><td>50%</td><td rowspan="3">1894</td><td>55%</td><td rowspan="3">1836</td><td>50%</td><td rowspan="3">1717</td></tr>
<tr><td>4/8</td><td>18%</td><td>10%</td><td>18%</td></tr>
<tr><td>8/16</td><td>32%</td><td>35%</td><td>32%</td></tr>
<tr><td colspan="2">Superplasticizer</td><td colspan="2">(ViscoCrete 3070) 2.10</td><td colspan="2">(ViscoCrete 1020x) 2.88</td><td colspan="2">(ViscoCrete 3070) 4.43</td></tr>
<tr><td colspan="2">Aerant</td><td colspan="2">-</td><td colspan="2">(Sika Antigelo) 3.61</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Water</td><td colspan="2">175</td><td colspan="2">176</td><td colspan="2">191</td></tr>
<tr><td colspan="2">Water-cement factor</td><td colspan="2">0.547</td><td colspan="2">0.486</td><td colspan="2">0.432</td></tr>
</table>

After the concrete mixtures were made, the following physical-mechanical properties for the given mixtures were tested: compressive strength and density.

Compressive strength

The compressive strength test was performed according to the standard SRPS ISO 4012 [13]. The compressive strength was tested on concrete blocks 15x15x15cm that were cured in a wet chamber and tested at 7 and 28 days, and the concrete mark was defined as the average stress in the sample exposed to fracture force of axial pressure.

Density

In the beginning of comressive strength test, the measurement of the sample weight was done and then the measurement of the dimensions of the tested cubes was performed. After the measurements, the density of hardened concrete can be calculated at 7 and 28 days when the samples were tested.

3. RESULTS OF EXAMINATION AND DISCUSSION

At the end of the tests, statistical data processing of the compressive strength and density at 7 and 28 days was done. Three different types of concrete mixtures were prepared, and for each of them three cubes were tested. For statistical data processing it was done: mean value, standard deviation and coefficient of variation. The mean value of the sample is calculated using the equation 1:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{1}$$

where: $\bar{x}$ is arithmetic average of n test results, x_i is the value of each individual sample of the n result and n is a number of samples. Determining the standard deviation value (σ) is performed by the equation 2:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}} \tag{2}$$

where σ is standard deviation. The coefficient of variation (C_u) is determined using equation 3, whereby the standard deviation should first be calculated:

$$C_v = \frac{\sigma}{\bar{x}} \tag{3}$$

where C_v is coefficient of variation of the tested property.

The mean values, the standard deviation, and the coefficient of variation obtained by the test are shown in Table 4. This statistical data processing also serves to determine deviations from the arithmetic average, as well as the representation of the variability, or whether it belongs to a homogeneous or hetoregenic set (C_u <30% - homogeneous set, C_u> 30% - heterogeneous set), or whether the variability is significantly lower from the arithmetic average.

Table 4 – Mean values, standard deviation and coefficient of variation of the results from the compressive strength and density test

Properties of hardened concrete		Concrete mixture		
		M1	M2	M3
7-days of compressive strength [MPa]	$\overline{x}$	37.9	43.83	46.43
	σ	0.20	2.62	1.12
	C_v	1.0	6.0	2.0
28-days of compressive strength [MPa]	$\overline{x}$	44.03	52.4	60.17
	σ	1.59	1.91	0.96
	C_v	4.0	4.0	2.0
7-days of density [kg/m^3]	$\overline{x}$	2392.33	2395.33	2356.00
	σ	7.50	9.29	8.00
	C_v	0.0	0.0	0.0
28- days of density [kg/m^3]	$\overline{x}$	2394	2384	2364.67
	σ	7.94	12.49	12.50
	C_v	0.0	1.0	1.0

It can be seen that standard deviation satisfies all the conditions in the test, except for the density testing at the age of 28 days. The variation coefficient values are lower and all the obtained results belong to the group of homogeneous set. The maximum compressive strength was obtained for the M3 mixture, while the minimum tensile strength was achieved for the M1 mixture.

3.1 Compressive strength

The values of compressive strength at 7 days are shown in Figure 2 left. It is observed that the M3 mixture has the maximum achieved compressive strength values, while the minimum values have been achieved for the M1 mixture. The same case occurs for compressive strength at 28 days, Figure 2 right.

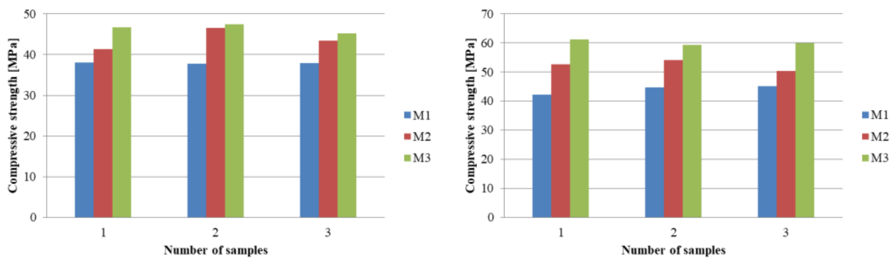

Figure 2 – Compressive strength at 7 days (left) and at 28 days (right)

All tested mixtures satisfy the requirement of SRPS U.E3.020 standard [14], compressive strength values at 28 days are greater than or equal to 40MPa, and all concrete mixtures can be applied to the production of concrete pavements for heavy traffic loads.

3.2 Density

In Figure 3 left, the volume of hardened concrete at 7 days is shown, while at 28 days it is shown in Figure 3 right. The maximum value of the density at 7 days is in the mixtures M2, but the minimum value was significantly achieved in the M3. Comparing density values at 28 days, it is noticeable that the maximum value was achieved for the M1 mixture, and the minimum value was achieved for the concrete samples of the M3 mixture.

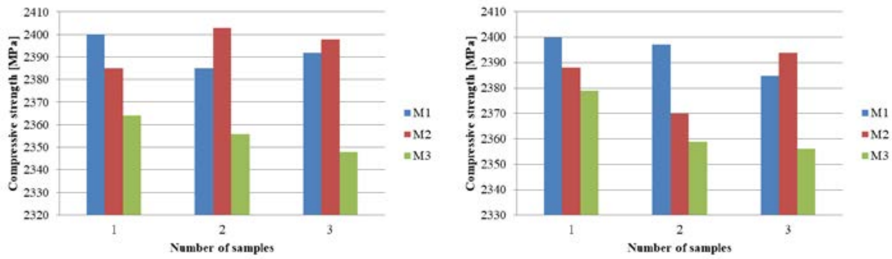

Figure 3 – Density at 7 days (left), density at 28 days (right)

4. CONCLUSION

According to the test analysis of different types of concrete mixtures, it can be concluded:

- the aggregate granulometric composition used for the preparation of concrete samples has no deviation from the reference area,
- all mixtures satisfy the criterion that the values of the compressive strengths are greater than 40MPa,
- because of the influence of the water-cement factor and the chemical additives used in the preparation of concrete samples, the density values of the samples are not uniform.

All concrete tested mixtures satisfy the requirement of SRPS U.E3.020 standard [14], and can be used to produce concrete pavements for heavy traffic loads.

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ИСПИТИВАЊЕ БЕТОНСКИХ МЕШАВИНА ЗА ИЗРАДУ БЕТОНСКОГ КОЛОВОЗА

Резиме: *Круту коловозну конструкцију представља бетонски коловоз. У овом раду, за потребе анализе урађено је испитивање три претходне пробе узорака за израду бетонског коловоза, а касније и испитивање чврстоће при притиску и запреминске масе. Испитивање је обављено након 7 и 28 дана, при чему су узорци неговани у лабораторијским условима. Испитане мешавине се разликују према врсти и количини цемента, агрегата, суперпластификатора, аераната и водоцементног фактора. На основу резултата урађених испитивања, за све три бетонске мешавине, чврстоће при притиску након 28 дана су веће или једнаке од 40MPa што доводи до закључка да све мешавине испуњавају услов за израду бетонског коловоза.*

Кључне речи: *бетонски коловоз, мешавине, чврстоћа при притиску*