IMPACTUL DISTRIBUȚIEI DIMENSIUNILOR PARTICULELOR DE AGREGAT ASUPRA CANTITĂȚILOR DE CIMENT ȘI ADITIVI NECESARE PENTRU OBȚINEREA UNOR COMPOZIȚII DE BETON AVÂND ACELEAȘI PROPRIETĂȚI

IMPACT OF THE RIVER AGGREGATE PARTICLE SIZE DISTRIBUTION ON THE QUANTITY OF CEMENT AND ADMIXTURES REQUIRED FOR MAKING OF CONCRETE MIXES OF THE SAME PROPERTIES

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The share of aggregate in concrete composition, in terms of volume is 70%-80%. The properties of fresh and hardened concrete depend on the aggregate properties, primarily on particle size distribution. The paper considered impact of particle size distribution of aggregates from two screening plants from the South Morava river on the properties of concrete. The intention was to make concrete mixtures with the aggregate which would have as identical particle size distribution, as similar consistency of fresh concrete as possible and same compressive strengths. For making of afore mentioned concrete mixes, the same sort of cement and same admixtures were used.

It was concluded that the difference in the particle size distribution of aggregate fractions had an impact on the composition of concrete mixes of the identical properties. Specifically, the quantities of cement, admixtures and water were different in the afore mentioned mixtures.

The technical specifications of the cement manufacturers include a recommended quantity of cement for specified concrete classes. It is concluded that these values are only rough guidelines. The same holds for the recommended quantities of admixtures. For that reason, every required concrete mixture must be verified in laboratory, i.e., previously tested.

***Keywords:** river aggregate, particle size distribution, cement, admixture, concrete*

1. Introduction

Concrete mixture, or fresh concrete as it is otherwise called, represents a complex, multi-component and poly-dispersive system which is formed in the concrete homogenization phase, when the solid component materials (aggregate and cement) are added certain amount of water. In such a system, there are finely dispersed particles of cement, very fine particles of aggregate and potentially some powder mineral admixtures, then considerably coarser grains of fine and coarse aggregate, as well as water, admixtures (concrete additives) and air bubbles [1-3].

It is best to consider the structure of fresh concrete as a system consisting of two main components: cement paste and aggregate. The cement paste composition always includes very fine particles of aggregate, as well as potentially powdery particles of certain mineral admixtures [4-6].

Cement paste properties depend on the ratio of solid and liquid phase: the increase of water content increases liquidity and reduces structural strength of hardened cement paste, i.e. cement stone Liquidity of the cement paste, apart from using certain amount of water, can be regulated by using of plasticizer and superplasticizer admixtures.

Concrete properties are strongly linked to the characteristics of the solid aggregate, the performance of the cement paste, and the interfacial region as well. Therefore, it is well recognized that concrete should be examined as a three-phase material consisting of aggregate, cement matrix and transition zone between them. In concrete terms, it can be concluded that properties of fresh concrete mixture depend on two basic factors: properties of components and structure of concrete mixtures [7-9].

Aggregate occupies 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influences the concrete's freshly mixed and hardened properties, durability, and economy [10].

Particle size distribution is the most important property of aggregate. Cohesion, workability and compactness of concrete mixture depend on the particle size distribution of aggregate mixture, as well as all important properties of hardened concrete: compressive strength, modulus of elasticity, shrinkage, water impermeability, durability etc. Optimum particle size distribution allows minimum energy expenditure for compaction of concrete mixture and minimum consumption of cement which contributes to economical execution of concrete works [11,12]. Several decades long experience showed that in determination of particle

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size distribution of aggregate for making concrete, the only acceptable solution is combining a certain number of aggregate fractions. In the process, one must take into account required concrete properties, method and conditions of transport and placement of fresh concrete [13].

According to the standard SRPS.UM1.057:1984, particle size distribution curves of aggregate mixtures are provided, for the concrete compliant with the German standard DIN 1048, which is recommended by the European commission for concrete. When designing concrete mixtures, it is intended that the particle size distribution curve is inside the prescribed referential area [14].

It should be had in mind that two aggregate mixtures can have identical particle size distribution but that concrete mixtures made from the mentioned aggregates can have different workability because of the considerable difference in shape and texture of the grains. Accordingly, without previous concrete tests, one cannot speak of determination of optimum aggregate mixture, but about speculation [15-16].

When particle size distribution is designed, in general, the following principles must be taken into consideration:

If high strength concrete is required and the aggregate with rounded grains is used (such as the river aggregate) the fine fraction quantity (0 – 4) mm can be reduced in the aggregate mixture. In that case, one should use particle size distribution which is closer to EMPA curve in the area related to the coarse aggregate.

In case the grain shape is not favorable, in order to obtain high strength concrete one should use aggregate mixtures containing higher quantity of fine fraction (0 – 4) mm, i.e. that one should adopt particle size distribution tending towards the Fuller curve for fine aggregate.

Particle size distribution of the aggregate mixture for making concrete affects the surface area of the aggregate on which depends the quantity of water required to cover all solid particles. It has a large influence on the workability of concrete mixture as well. On the other hand, workability depends on the quantity of water and cement [17-19]. There is an important requirement for good concrete workability: it must contain a sufficient amount of finest materials – smaller than 125 microns.

If interdependence of cement and particle size distribution of the aggregate in concrete mixture is observed, it can be concluded that when dosage of cement is high, the need for the finest fractions aggregate decreases, and vice versa. If particle size distribution of fine aggregate is such that it lacks the finest grains, then increase of fine/coarse aggregate ratio cannot be appropriate corrective measure. In this way, one can obtain a surplus of medium sized grains and increase stiffness of concrete mixture [20-22].

In case of the granulated aggregate, granulation and general specific surface area of grains are correlated. However, there are many different particle size distribution curves which correspond to the same surface area of the grain. If particle size distribution includes large grains of coarse aggregate, then total specific surface area decreases, and consequently decreases the required quantity of water, but this ratio is not linear. By increasing specific surface area of aggregate grains at constant w/c ratio, compressive strength of concrete is reduced [23].

Cement/aggregate ratio affects the strength of all concretes whose strengths range around 35 N/mm^2 or more. Cement / aggregate ratio is only a secondary factor on which concrete strength depends, and it was determined that at constant water /cement ratio a leaner mixture can produce concretes having higher compressive strengths. This is correlated with the phenomenon of water absorption in aggregate. Namely, the higher the aggregate quantity, the more water will be absorbed, which means that effective water/cement ratio will be reduced [24-25].

Much as it is important to conceive a “good” particle size distribution, it is even much more important to maintain that composition. Otherwise, we will obtain concretes of different workability, and if water quantity is changed, we will obtain concretes of various strengths [26].

2. Materials and experimental studies

Experimental test were performed in the Laboratory for Building materials of the Faculty of Civil Engineering and Architecture of Niš. The goal of the research was to test the effects of particle size distribution of aggregate from two screening plants obtained from the South Morava river on concrete properties.

Two batches of six concrete mixes (a total of twelve) were made, having the following properties, from the river aggregate obtained from two screening plants located on the South Morava river:

R - near to Niš 1.MB30/ D max = 16 mm, M200 V8 MS“0”, 2. MB35/ D max = 16 mm, M200 V8 MS“0”, 3. MB35/D max = 31.5 mm, M200 V8 MS“0”, 4. MB45/ D max = 16 mm, M200 V8 MS“0”, 5. MB45/ D max = 16 mm, M200 V6 MS“0” and 6. MB50/ D max = 16 mm, M200 V8 MS“0” – for pre-stressed beams cast in situ.

R - distant from Niš 7.MB30/ D max = 16 mm, M200 V8 MS“0”, 8. MB35/ D max = 16 mm, M200 V8 MS“0”, 9. MB35/D max = 31.5 mm M200 V8 MS“0”, 10. MB45/ D max = 16 mm, M200 V8 MS“0”, 11. MB45/ D max = 16 mm, M200 V6 MS“0” and 12. MB50/ D max = 16 mm, M200 V8 MS“0” – for pre-stressed beams cast in situ.

Special properties of concretes and compressive strength were determined according to the national standards, concretely: frost action resistance was determined according to the national standard SRPS U.M1.016:1992, Concrete – Testing concrete resistance to frost action. The designations of concrete resistance to frost action are: **M – 50, M – 100, M – 150, M – 200, M – 250 and M – 300**, the numbers marking the highest number of cycles of alternate freezing and thawing which must be sustained by the concrete specimens.

Determination of pressurized water penetration was made according to the national standard SRPS U.M1.015:1978, Concrete – Hardened concrete – determination of penetration of pressurized water. The national code for concrete BAB 87, which a standing code, makes references to the mentioned standard which defines the so called water impermeability class: **V -2, V – 4, V -6, V – 8 and V – 12**. The numbers denote the pressure of water expressed in bars at which there must be no dampness on the top surface of at least five to six specimens which are tested, in order to assign the concrete with the corresponding water impermeability class.

Testing of concrete surface resistance to the action of frost and defrosting salt is conducted according to the provisions of the national standard SRPS U.M1.055:1984, Concrete - Testing of concrete surface resistance to the action of frost and defrosting salt. The tests are performed by fitting on the tested surface of the concrete specimen a frame having the height of 10 mm whose joint with the concrete surface is water impermeable. A solution of 3 % NaCl is poured into the frame, and its 3 mm thick layer is maintained for seven days in laboratory conditions. During that period, concrete absorbs the salt solution. After that, concrete is exposed to 25 cycles of alternate freezing and thawing. The material that has scaled off is collected and weighed and the result is expressed in mg/mm^2. The designation for the mentioned concrete test is **MS "number"**, damage degree: **0** – no scaling, **1** – weak scaling, **2** – medium scaling and **3** – severe scaling.

Designations of each concrete mix was mentioned according to the required concrete class, which according to the national code for concrete BAB 87 is marked with MB "number", where MB means concrete class, and the number denotes the guaranteed concrete compressive strength.

Compressive strength was tested according to the national standard SRPS ISO 4012:2000 Concrete – Determination of specimen compressive strength.

On the basis of the previous statements, the designations of the mixes were adopted according to the following significances MB – concrete class, M – resistance to frost action, V- water impermeability class, MS – degree of resistance of concrete to the simultaneous action of frost and defrosting salt, D_{max} – maximum size of aggregate grains used to make concrete.

The intention was to make concrete mixtures with the aggregate which would have as identical particle size distribution, as similar consistency of fresh concrete as possible and same compressive strengths. Same types of cement and admixtures were used for making of concrete mixes. The consistency of fresh concrete obtained by slump flow test (Abrams' cone) S4 on the placement site was required, for the transport time of 65 minutes. Concrete was placed by pumping. The required properties of the hardened concrete were : compressive strengths and special properties such as –, resistance to action of frost and salt and water impermeability.

Among the mentioned mixtures, two concrete mixtures were made (for aggregates from both screening plants) for the purpose of production of pre-stressed beams cast in situ. Different types of cement were used for these concrete mixtures. Maximum permissible total w/c ratio was 0,50 because it is the maximum permissible value for concrete mixes destined to infrastructural buildings such as: bridges, tunnels and hydraulic structures. Maximum aggregate grain size was different for demanded concrete mixtures. For a number of mixtures it was Dmax =16 mm, and for the others it was maximum grain size requirement, Dmax =31.5 mm. In order to achieve frost action resistance, according to the national standard BAB 87, the necessary percentage of entrained air should be 5 to 7 %, for concrete mixtures having maximum grain size D= 16 mm, and 3% to 5% for concrete mixtures having maximum aggregate grain size D = 31.5 mm. In order to achieve a consistency S4, minimum w/c ratio 0.50, and required special properties of concrete which were previously mentioned as well as pumpability of concrete for transport time of 65 minutes, two admixtures were used: one was superplasticizer type, and the other of the air entrainer type. It should be stressed that making of concrete mixtures took place at air temperature of 20 ± 2^0C and relative humidity of 65% ± 5 %.

For making concrete mixtures, cement "Holcim" Novi Popovac was used, having designation CEM II (A-L) 42,5R and Holcim CEM I 52,5 R (for concrete class 50).

Two batches of previously mentioned concretes were made. The first of the mentioned batches was made with the aggregate from the formerly mentioned screening plant - South Morava river aggregate which is located nearer to the city of Niš, and the second batch was made with the aggregate from the latter screening plant - South Morava river aggregate which is located distant from the city of Niš. Three aggregate fractions - 0/4, 4/8 and 8/16 mm were used for a certain number of concrete mixtures and for some of them, the requirement was to use all four aggregate fractions - 0/4, 4/8 and 8/16 mm and 16/31.5 mm. The used admixtures were Superfluid 21 M Eko and

Poročinitel. Superfluid 21 M Eko, manufactured by Ading – Skoplje, is a superplasticizer produced on the polycarboxylate basis, intended for production of easily transporting concrete, for which the main demand is extreme maintaining of consistency and good rheological properties of fresh concrete. It is used for transported concretes, pumped concretes, improving the workability and ensuring higher final strengths. Poročinitelj is an air entrainer of the same manufacturer Ading – Skoplje. Water used was from city supply network.

Prior to making of concrete mixtures, particle size distribution of fractions of the river aggregates from both screening plants was tested. Particle size distributions of the fractions: 0/4, 4/8., 8/16 mm and 16/31.5 mm of the screening plant of river aggregate located near the city of Niš (adopted designation R – nearer to Niš) were determined by the dry sieve method according to the national standard SRPS B.B8.029:1982. The same tests were performed for the aggregate fractions: 0/4, 4/8, 8/16 mm and 16/31.5 mm from the other screening

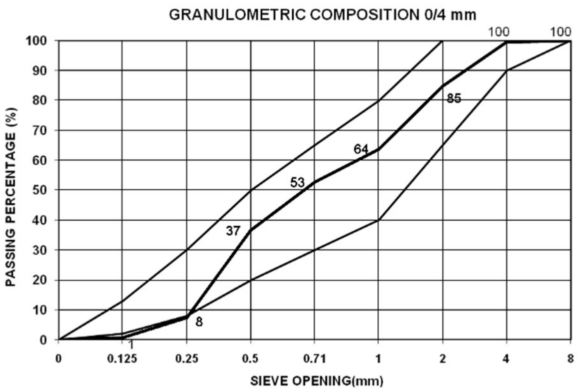


Fig. 1 - Particle size distribution of fraction 0/4 mm for aggregate R – near to Niš.

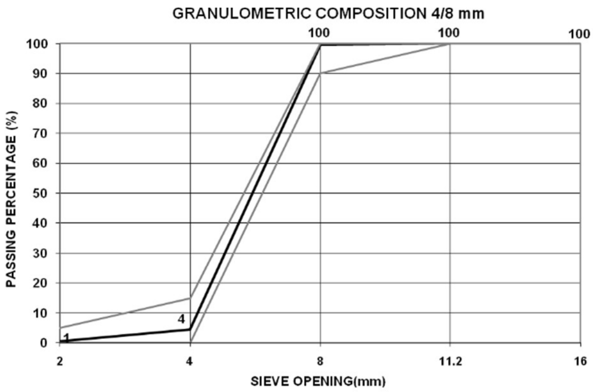


Fig 2. - Particle size distribution of fraction 4/8 mm for aggregate R – near to Niš.

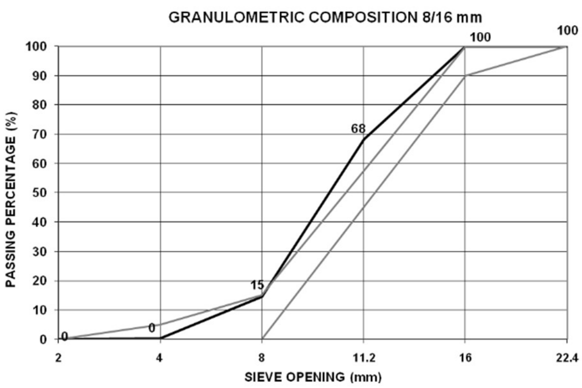


Fig. 3 - Particle size distribution of fraction 8/16 mm for aggregate R – near to Niš .

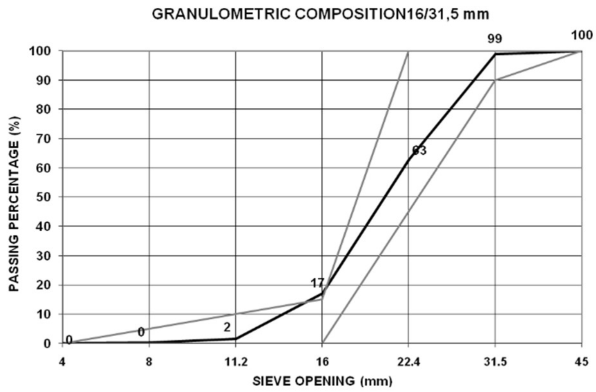


Fig. 4 - Particle size distribution of fraction 16/31.5 mm for aggregate R – near to Niš.

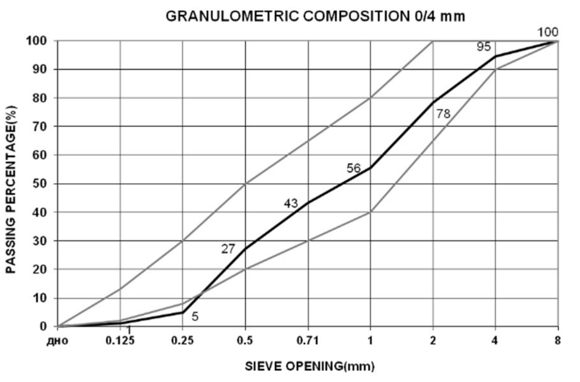


Fig. 5 - Particle size distribution of fraction 0/4 mm for aggregate R – distant from Niš

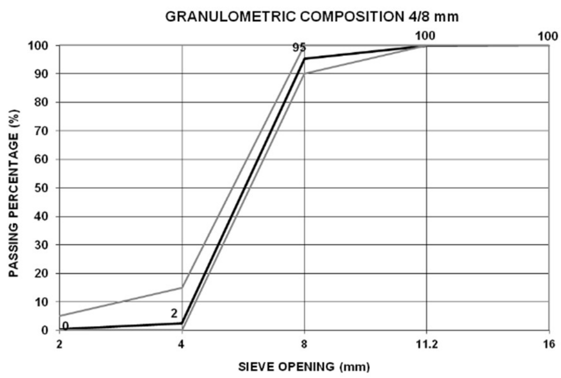


Fig. 6 - Particle size distribution of fraction 4/8 mm for aggregate R – distant from Niš.

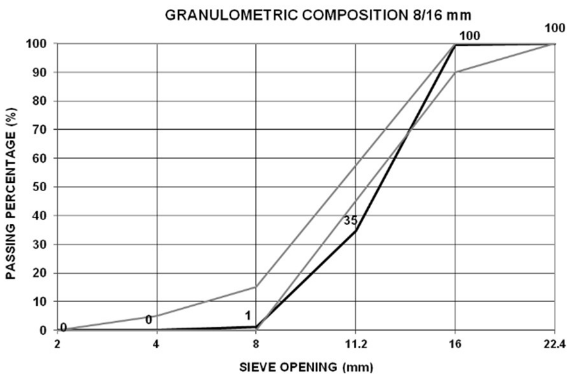


Fig. 7 **-** Particle size distribution of fraction 8/16 mm for aggregate R – distant from Niš.

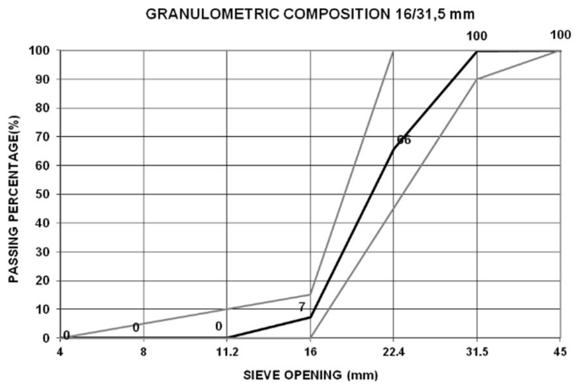


Fig. 8 - Particle size distribution of fraction 16/31.5 mm for aggregate R – distant from Niš.

Table 1

Shares of fractions in particle size distribution of the aggregate mixtures for all designed concrete mixes expressed in percents

Fraction type	First screening plant R – near to Niš Three-fraction aggregate mixture	Second screening plant R – distant from Niš Three-fraction aggregate mixture	First screening plant R – near to Niš Four-fraction aggregate mixture	Second screening plant R – distant from Niš Four-fraction aggregate mixture
0/4 mm	40	40	38	38
4/8 mm	25	25	12	12
8/16 mm	35	35	18	18
16/31.5 mm	-	-	32	32

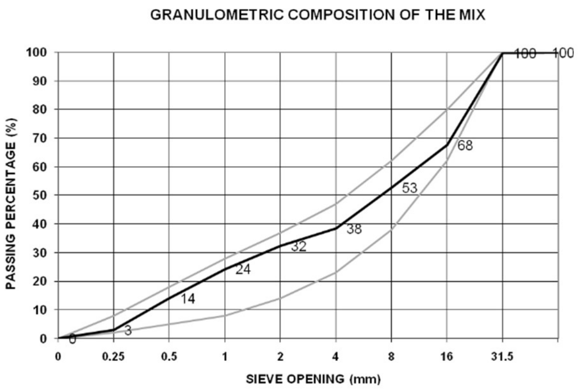


Fig. 9. - Particle size distribution of the mixture for first aggregate (- R – near to Niš) with three fractions .

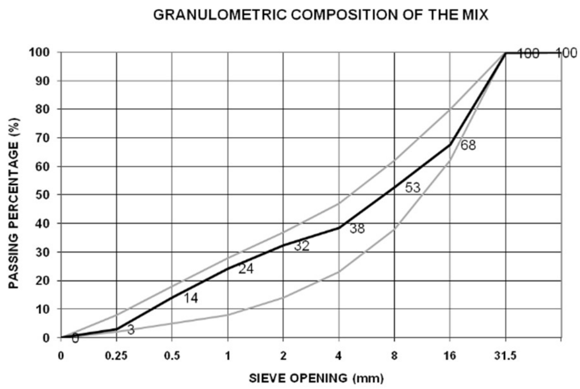


Fig. 10 - Particle size distribution of the mixture for first aggregate (- R – near to Niš) with four fractions.

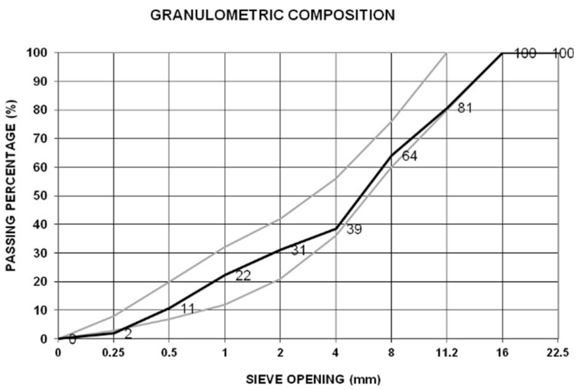


Fig. 11 **-** Particle size distribution of the mixture for second aggregate (- R – distant from Niš) with three fractions.

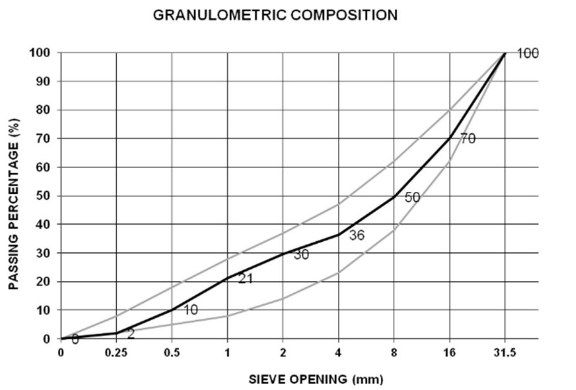


Fig. 12 **-** Particle size distribution of the mixture for second aggregate (- R – distant from Niš) with four fractions.

plant of the river aggregate from the South Morava which is located distant from the city of Niš (adopted designation: R – further from Niš). Particle size distribution of fractions 0/4 mm, 4/8 mm, 8/16 mm and 16/31.5 mm of the first screening plant (R – near to Niš) showed in Figures 1, 2, 3 and 4. Particle size distribution of fractions 0/4 mm, 4/8 mm, 8/16 mm and 16/31.5 mm of the second screening plant (R – distant from Niš) showed in Figures 5, 6 , 7 and 8.

For concrete mixtures made with three or four fractions of aggregate **R – near to Niš**, the adopted particle size distribution mixtures are presented in Figures 9 and 10.

On the basis of previously adopted particle size distributions it was attempted to create concrete mixtures with the aggregate R – distant from Niš, having similar particle size distribution - Figures 11 and 12.

Shares of fractions in particle size distribution of the aggregate mixtures for all designed concrete mixes expressed in percents are provided in Table 1.

Based on the adopted particle size distributions of aggregates for making of all kinds of concrete, previous concrete mixtures were made for required consistency conditions, duration of transport and for required properties of hardened concrete. In table 2 were provided compositions of all concrete mixtures.

Methods of investigations were: making and curing of test specimens for strength tests - SRPS ISO 2736-2:1997; determination of compressive strength of test specimens - SRPS ISO 4012:2000; slump test - SRPS ISO 4109:1997; determination of air content of fresh concrete – SRPS ISO 4848:1999, determination of density of hardened concrete: SRPS ISO 6275:1997; determination of density of compacted fresh concrete: SRPS ISO 6276:1997; measuring temperature of concrete: SRPS U.M1.032:1981.

Used standards and codes were: design of concrete mixtures category B.II - Code for concrete and reinforced concrete (PBAB 87); dimensions, tolerances and applicability of test specimens - SRPS ISO 1920:1997; classification by compressive strength - SRPSU.M1.021:1997; classification by consistency - SRPS ISO 4103:1997.

3. Results and discussion

In Tables 2 and 3, are provided data of the concrete mixtures compositions. Fresh concrete consistency was measured and monitored in the course of 60 minutes, with the purpose of maintaining it. After the mentioned time, consistency decreased in the majority of concrete mixes. In a number of them, the superplasticizer

Table 2

Compositions of concrete mixes for the first river aggregate screening plant (R – near to Niš)

Designation of concrete mixture	Quantity of cement per 1 m^3 of concrte	Quatntity of water	Quantity of aggregate for 1m^3 of concrete per fractions								Quantity of Superplasticizer 21 M Eko, admixture added to make concrete mixture		Quantity of Superplasticizer 21 M Eko, admixture, added in situ Time t = 60 min.		Air entrainer – "Poročinitelj" added to make concrete mixture	
			0 -4mm		4-8 mm		8-16 mm		16-31.5 mm							
	[kg[	[kg[	[%[	[kg]	[%[	[kg]	[%[	[kg]	[%[	[kg]	[kg]	[%]	[kg]	[%]	[kg]	[%[
Aggregate (R – near to Niš) CEM II A-L 42,5 R																
1	360	169,2	40	716	25	447	35	627	0	0	3.60	1.0	0.036	0.01	0.108	0.03
2	380	171	40	704	25	440	35	616	0	0	3.80	1.0	0.76	0.2	0.114	0.03
3	360	180	38	688	12	217	18	326	32	579	3.6	1.0	0.36	0.1	0.108	0.03
4	440	189,2	40	692	25	432	30	606	0	0	5.72	1.3	0	0	0.110	0.025
5	420	180,6	38	665	12	210	18	315	32	560	4.20	1.0	0	0	0.105	0.025
Aggregate (R – near to Niš) CEM I 52,5 R																
6	450	178.0	44	757	20	344	36	619	0	0	3.60	0.8	0	0	0.09	0.02

Table 3

Compositions of concrete mixes for the second river aggregate screening plant (R – distant from Niš)

Designation of concrete mixture	Quantity of cement per 1 m³ of concrte	Quatntity of water	Quantity of aggregate for 1m³ of concrete per fractions: 0 -4mm		4-8 mm		8-16 mm		16-31.5 mm		Quantity of Superfluid 21 M Eko, admixture, added to make concrete mixture		Quantity of Superfluid 21 M Eko, admixture, added in situ Time t = 60 min.		Air entrainer– "Poročinitelj" added to make concrete mixture	
	[kg[	[kg[	[%[	[kg]	[%[	[kg]	[%[	[kg]	[%[	[kg]	[kg]	[%]	[kg]	[%]	[kg]	[%]
Aggregate (R – distant from Niš) CEM II A-L 42,5 R																
7	380	178.6	40	698	25	436	35	611	0	0	3.80	1.0	0,038	0,01	0.114	0.03
8	400	184	40	692	25	432	35	606	0	0	3.20	0.8	0,80	0.2	0.12	0.03
9	380	174.8	38	676	12	214	18	320	32	570	3.42	0,9	0.38	0.1	0.076	0.02
10	440	189.2	40	688	25	430	30	602	0	0	4.84	1.1	0	0	0.132	0.03
11	420	180.6	38	663	12	209	18	314	32	559	4.20	1.0	0.42	0.1	0.105	0.025
Aggregate (R – distant from Niš) CEM I 52,5 R																
12	460	174.8	44	680	20	425	36	595	0	0	3.68	0.8	0.69	0.15	0.115	0.025

Table 4

Data on fresh concrete mixes of the first river aggregate screening plant (R – near to Niš)

No and designation of concrete mixture	Air temperature in the laboratory °C	Temperature of water for making concrete °C	Temperature of fresh concrete °C	Classification of consistency by slump	Air content of fresh mixed concrete %	Density kg/m³
1. MB30/ D max = 16 mm M200 V8 MS"0"	21.2	19.6	22.0	S4 (220 mm) after 7 min S4 (170 mm) – after subsequent addition of superplasticizer t = 65 min.	6.2	2300
2. MB35/ D max = 16 mm M200 V8 MS"0"	21.0	19.4	21.3	S4 (190 mm) after 7 min S4 (180 mm)- after subsequent addition of superplasticizer = 65 min.	5.3	2305
3. MB35/ D max = 31.5 mm M200 V8 MS"0"	19.1	17.3	21.3	S4 (210 mm) after 7 min S4 (170 mm) - after subsequent addition of superplasticizer t = 65 min.	4.7	2340
4. MB45/ D max = 16 mm M200 V8 MS"0"	18.5	16.4	21.6	S4 (170 mm) after 7 min S4 (160 mm) – No subsequent addition of admixtures	6.1	2340
5. MB45/ D max = 31.5 mm M200 V6 MS"0"	18.8	16.8	21.5	S4 (170 mm) after 7 min No subsequent addition of admixtures	4.2	2346
6. MB50/ D max = 16 mm M200 V8 MS"0"	19.0	17.1	20.4	S4 (190 mm) after 7 min No subsequent addition of admixtures	5.0	2345

Table 5

Data on fresh concrete mixes of the second river aggregate screening plant (R – distant from Niš)

No and designation of concrete mixture	Air temperature in the laboratory °C	Temperature of water for making concrete °C	Temperature of fresh concrete °C	Classification of consistency by slump	Air content of fresh mixed concrete %	Density kg/m³
7. MB30/ D max = 16 mm M200 V8 MS“0””	20.0	17.5	22.2	S4 (200 mm) after 7 min S4 (170 mm) - after subsequent addition of superplasticizer t = 65 min.	5.8	2310
8. MB35/ D max = 16 mm M200 V8 MS“0”	20.5	16.5	23.2	S4 (180 mm) after 7 min S4 (160 mm)- after subsequent addition of superplasticizer t = 65 min.	5.3	2305
9. MB35/ D max = 31.5 mm M200 V8 MS“0”	19.1	17.3	21.3	S4 (160 mm) after 7 min S4 (160 mm) – after subsequent addition of superplasticizer t = 65 min.	4.0	2340
10. MB45/ D max = 16 mm M200 V8 MS“0”	21.0	20.1	23.0	S4 (220 mm) after 7 min S4 (160 mm) - No subsequent addition of admixtures	5.2	2350
11. MB45/ D max = 31.5 mm M200 V6 MS“0”	20.5	18.0	21.3	S4 (210 mm) after 7 min S4 (170 mm) - after subsequent addition of superplasticizer t = 65 min.	4.2	2350
12. MB50/ D max = 16 mm M200 V8 MS“0”	20.6	18.5	24.0	S4 (210 mm) after 7 min S4 (170 mm) - after subsequent addition of superplasticizer t = 65 min.	6.1	2302

admixture was subsequently added, with the goal of achieving initial, required consistency. Density of concrete mixtures was also, determined. In the Tables 4 and 5, data on fresh concrete are provided. On the hardened concrete, compressive strengths were measured after 2, 7 and 28 days. It is necessary to emphasize that according to the national standard BAB 87 when concrete mixes are designing, a strength value higher or no less than 8 N/mm^2 is necessary to consider higher than the designed concrete class. Compressive strength for designed concrete mixes was tested on the concrete specimens having the shape of cub with the sides of 15 cm. Regarding that the national standard BAB87 requires that the class of concrete is defined according to the measured compressive strengths of the concrete specimens of cubical shape with the sides of 20 cm, the compressive strengths which were obtained by the tests were increased for 5%, according to the correlation coefficient of concrete cube specimens having sides of 15 and 20 cm.

When the concrete mixture MB30/ D max = 16 mm, M200 V8 MS“0” was made with the second aggregate type, the composition of the concrete mixture was the same as the concrete mixture made with the first aggregate type (R – near to Niš). Concretely, the same quantity of cement, aggregate, water and admixture were adopted.

However, the obtained compressive strengths after 28 days were lower than the required ones. The same happened in case of the concrete mix 8 - MB35/ D max = 16 mm, M200 V8 MS“0”.

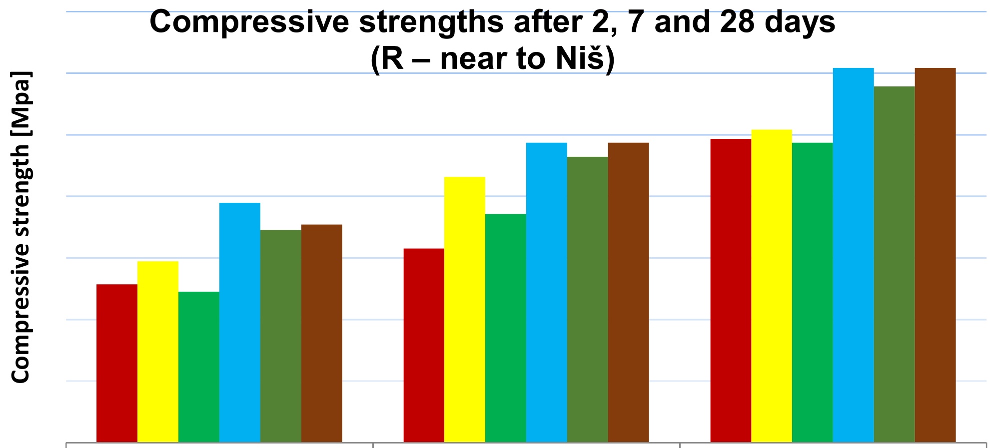
It was concluded that the cement quantity has to be increased in order to provide higher compressive strength and retain the required consistency and pumpability of concrete..

However, in case of the concrete mixes where the cement dosage was considerably higher, concretely 420 kg and more, it was not necessary to increase the cement quantity, because there was sufficient cement to compensate for the difference in grading of the aggregate fractions from the two mentioned screening plants, and the required compressive strengths were achieved.

In Figures 13 and 14 are given the obtained values of compressive strengths for concrete mixtures made with both aggregates.

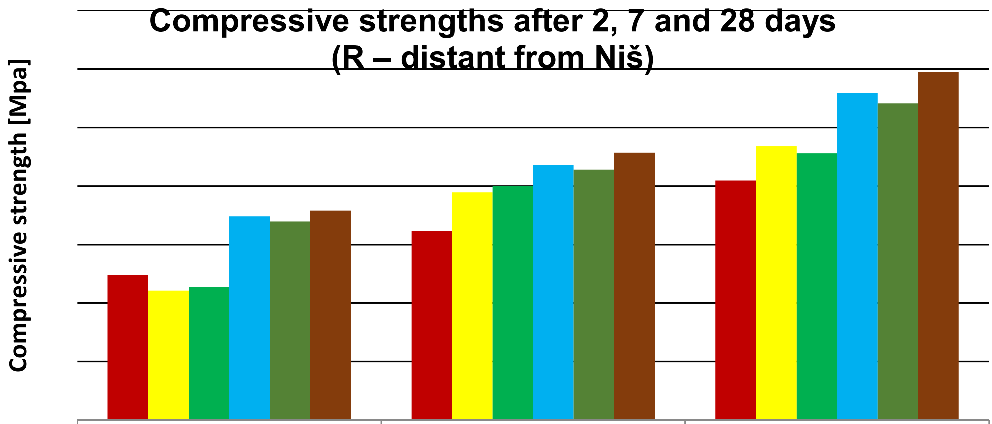
Based on the composition of the designed concrete mixes provided in Tables 2 and 3, the following conclusions can be drawn:

Irrespective of almost equal adopted particle size distribution curves for the river aggregates from both screening plants, it was necessary to use different quantity of cement for making concrete classes MB30/ D max = 16 mm, M200 V8 MS“0, in order to obtain the required concrete class. For making of the mentioned concrete mixture with the river aggregate from the second screen plant (R – distant from Niš), it was necessary to use a higher quantity of cement – 20 kg more, which is around 6 % more in comparison with the same mixture made with the river aggregate from the first separation (R – distant from Niš). It is important to point out that the obtained compressive strengths after 28 days are higher for the concrete mixture with the aggregate from the first screening plan (R – near to Niš), which are made with a smaller quantity of cement. If the sieve curves of fractions of both aggregates are



	2	7	28
1	25.7	31.5	49.3
2	29.4	43.1	50.8
3	24.5	37.1	48.7
4	38.9	48.7	60.8
5	34.5	46.4	57.8
6	35.41	48.67	60.81

Fig. 13 - Compressive strengths after 2, 7 and 28 days for concrete mixtures made with aggregate R – near to Niš .



	2	7	28
7	24.7	32.3	40.9
8	22.1	38.9	46.8
9	22.7	40	45.6
10	34.8	43.6	55.9
11	33.9	42.8	54.1
12	35.8	45.7	59.5

Fig. 14. - Compressive strengths after 2, 7 and 28 days for concrete mixtures made with aggregate R – distant from Niš .

considered, it can be concluded that their fractions of 0 – 4 mm and 8 – 16 mm are considerably different. The first fraction from the first river aggregate screening plant (R – near to Niš) has a higher percentage of passage through the sieve in comparison with the second river aggregate (R – distant from Niš). The third fraction from the first screening plant of the river aggregate (R – near to Niš) has oversized grains, and from the second screening plant (R – distant from Niš) has undersized grains on the interim sieve having 11.2 mm opening. Difference in particle size distribution of the river aggregates from both screening plants caused the difference in composition of the mentioned mixtures.

In case of the mixture MB35/ D max = 16 mm, M200 V8 MS“0” the similar situation emerged regarding the amount of cement. Water/cement ratio differed for 0.01, and the quantity of superplasticizer was different, with a goal of achieving the required consistency. The obtained strengths after 28 days, as in the previous mix design were higher for concrete which was made with the river aggregate from the first screening plant regardless of the fact that in its making a smaller quantity of cement was used.

The same phenomenon was observed for the concrete mixture carrying designation MB35/ D max = 31.5 mm, M200 V8 MS“0”. In the making of this concrete mix, fourth fraction of the aggregate was used as well, which considerably contributes increase of compressive strength. For the previously mentioned concrete mixture, the concrete made with the river aggregate from the second screening plant (R-distant from Nis) exhibited 7% lower compressive strength after 28 days than the concrete of the same required properties which was made with the aggregate from the first screening plant (R – distant from Niš). At the same time, less cement was used for making of that concrete mixture, and w/c ratio was lower in comparison with the concrete mixture of same required properties which was made with the aggregate from the first screening plant (R – distant from Niš).

In case of mix designs MB45/ D max = 16 mm, M200 V8 MS“0” and MB45/ D max = 31.5 mm, M200 V6 MS“0” there was no difference in the amount of cement and water cement ratio for both types of aggregates. The difference in the obtained strengths after 28 days amounted to 9%, that is, 7%. It is obvious that the mass of cement used for making of concrete mixes: 440 kg for concrete MB45/ D max = 16 mm, M200 V8 MS“0” and 420kg for concrete MB45/ D max = 31.5 mm, M200 V6 MS“0”, eliminated the impact of difference in particle size distribution of fractions of these two aggregates on composition of previously mentioned concrete mixes.

In case of concrete mixtures MB50/ D max = 16 mm, M200 V8 MS“0”, the condition was to use the cement CEM I 52.5 R for construction of pre-stressed beams in situ. In the making of the previously mentioned concrete mixture with the aggregate from the first screening plant (R – near to Niš) the amount of cement was increased with 2%, and w/c ratio was reduced by comparison with the same mixture with the aggregate from the second screening plant R – distant from Niš). The obtained values of compressive strengths were almost identical, i.e. the difference is negligible (60.81 N/mm^2 and 59. 5 N/mm^2). It was attempted to determine in this way what cement savings can be made when making the concrete mixture with the river aggregate from the first screening plant in comparison to the aggregate from the second screening plant.

The mix designs made with the aggregate from the first screening plants provide more cost-efficient compositions for the required properties of concrete mixtures. The reason for this is, as was mentioned previously, particle size distribution of the first and third aggregate fractions in comparison to the corresponding fractions from the other river aggregate screening plant.

All concrete mixtures fulfilled the required special properties; resistance to frost action – there was no flaking and cracking, resistance to simultaneous action of frost and salt MS „0“, and in terms of water impermeability of concrete, water penetration was maximum 10 mm.

Superplasticizer and air entrainer admixtures were added during making of concrete mixes. Regarding that for a duration of the mixing time of 60 minutes (simulated transport time) the consistency decreased, a subsequent necessary quantity of superplasticizer had to be added at the location of concrete placing. However, if Tables 5 and 6 are observed, it can be concluded that concrete mixes made with the river aggregate of the first screening plant for the mixtures MB45/ D max = 16 mm, M200 V8 MS“0”, MB45/ D max = 31.5 mm, M200 V6 MS“0” and MB50/ D max = 16 mm, M200 V8 MS“0” retained consistency into the S 4 class after 60 minutes even though superplasticizer was not subsequently added. Regarding the concrete mixtures made with the river aggregate from the second screening plant, no subsequent superplasticizer was added only in the mixture MB45/ D max = 16 mm, M200 V8 MS“0”.

All concrete mixtures were made in laboratory conditions: temperature 20 $\pm$ 2^0 C, relative air humidity was 65 $\pm$ 5 %. It should be pointed out that the construction site conditions of concrete factorings during transport and placing of concrete are different. Admixture correction is performed in accordance with them.

4. Conclusion

The same type of river aggregate from two screening plants which are located at a relative small distance one from another, in design of concrete mixtures having identical properties and very similar or almost equal particle size distribution curves mixtures of both aggregates will not produce the concretes having the same composition.

The answer for the mentioned difference in composition of concrete mixes lies in the difference of particle size distribution of fractions of the river aggregate from two screening plants of the South Morava river aggregate.

In concrete terms, the grains which by size are found between two sieves, are different in size for the same type of river aggregates from two separations. This implies a conclusion that particle size distribution of the aggregate fractions has a great impact on what type of concrete will be obtained, in terms of composition and properties, irrespective of their identical adopted particle size distribution of the mixture for the same type of river aggregate.

The previously mentioned impact is dominant for the concrete mixtures which contained up to 400 kg of cement per 1 m^3 of concrete. In excess of this quantity, the difference in particle size distribution of river aggregate fractions from two mentioned screening plants did not cause differences in concrete mixtures compositions, i.e. they were identical.

From the previous statement, it can be concluded that in case of large quantities of cement using for making of concrete mixtures, the difference of particle size distribution of fractions of two aggregates of the same river origin, but from different screening plants, did not have any effect on concrete composition. In case of these concretes, only consistency keeping in time was different; so in the concrete mixtures which contained more than 400 kg of aggregate, and they were made with the aggregate from second screening plant subsequent addition of admixtures was necessary. This is explained by the fact that the first fraction of this aggregate contains a lower percentage of fine grains in comparison with same fraction of the river aggregate from the first screening plant.

In the technical specification of cement manufacturers, there are recommended quantities of cement for the recommended quantities of admixtures. It is concluded that these values are only loose guidelines. The same holds for the recommended quantities of admixtures. For that reason, every required concrete mix should be tested in laboratory, through preliminary testing.

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Detaliu al coloanei de susținere a unei scări încolăcite și a balconului ei (pg. 15 - Nicolae St.Noica - ATENEUL ROMÂN ŞI CONSTRUCTORII SĂI)

Detaliu de scară și pardoseală în corpul dinspre strada Poșta Veche (pg. 123 - Nicolae St.Noica - ATENEUL ROMÂN ŞI CONSTRUCTORII SĂI)