MIX DESIGN OF CONCRETE FOR AVALA TOWER

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Summary: *In the world, new kinds of concrete are constantly being put to use. In the last few years we have made self-compacting concrete in Serbia. This kind of concrete will be use for construction of Avala tower. The contractor chose self-compacting concrete because of the need for excellent finishing, short deadlines and lower cost of building.*

Key words: *Self-compacting concrete, high strength, materials.*

1. INTRODUCTION

The common practice in the world is to assign building of major structures to companies able to do the job as quickly and cheaply as possible. There are many ways to shorten the construction time. When it comes to concrete structures one way is to use new materials, especially new kinds of concrete. In the world, new kinds of concrete are constantly being put to use. In our country this trend has just started.

Avala tower in the vicinity of Belgrade is one of rare examples of major structure under construction in Serbia at the moment. It is financed by the Republic of Serbia, and the main contractor is "Ratko Mitrovic" –"Dedinje" The contractor chose self-compacting concrete because of the need for excellent finishing, short deadlines and lower cost of building.

The tower design is the same as it was before the demolition. The columns should be made of MB 50(C40/50), and the core of the column should be made of concrete make MB 60 C(50/60).

Preliminary trials were carried out at IMS Institute at the request of the contractor.

After discussion about the use of possible materials the conclusion was reached that to get these high performance products it was necessary to use crushed eruptive aggregates, special cements and admixtures with high water reduction.

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2. MATERIALS USED IN MIX DESIGN

2.1. CEMENT

Cements from factories in Beocin and Kosjeric were used. Beocin cement factory delivered pure Portland cement PC 42.5R CEM I 42.5R), while the make of cement from Kosjeric was PC 20S 42.5R (CEM II/A-S 42.5N). Since the early strengths of concrete and as economical solution as possible were required, it was expected from the Beocin factory to heighten control and to use larger specific surface according to Blaine. In the first delivery the specific surface of cement was 4720 cm^2/g, but this was later reduced to 4380cm^2/g in agreement with the representatives of the IMS Institute. The comparison of results showed that the difference between the early and final strengths of concrete was negligible, and the limit for specific surface was set to 4100±200 cm^2/g.

Cement made in Kosjeric came from standard production. Physical and mechanical properties of types of cements used are given in table 1.

Table 1. Phisical and mechanical properties of cement

	Cement I	Cement II
Specific surface (Blaine), (cm^2/g)	4730	4380
Fineness – solids 0.09 mm (%)	0.2	0.5
Bulk density, (g/cm^3)	3.14	3.12
Bending strenght on 2 days (N/mm^2)	6.3	5.2
Bending strenght on 7 days (N/mm^2)	8.2	7.5
Bending strenght on 28 days (N/mm^2)	8.2	8.5
Compresive strenght on 2 days (N/mm^2)	25.8	23.1
Compresive strenght on 7 days (N/mm^2)	42.6	37.0
Compresive strenght on 28 days (N/mm^2)	52.0	45.8

Detailed analysis of chemical composition of La Farge cement was carried out: ordinary analysis and energy-dispersive, x-ray fluorescent spectrometry (EDXRF). Comparative results are given in table 2.

Table 2. Classical testing and testing on EDXRF

	EDXRF	Stan.		EDXRF	Stan.
SiO_2, %	20.12±0.10	19.94	K_2O, %	0.60±0.011	0.60
Al_2O_3, %	6.05±0.050	6.06	MnO, %	0.109±0.0042	0.100
Fe_2O_3, %	2.59±0.011	2.64	Loss on ignition, %	1.14	1.14
CaO, %	64.09±0.090	64.46	Insoluble residue in HCl/Na_2CO_3, %	-	0.20
MgO, %	2.13±0.193	2.06	Insoluble residue in HCl/KOH, %	-	0.09
SO_3, %	3.08±0.023	3.15	CO_2, %	-	0.18
S^{2-}, %	-	0.00	Cl^-, %	0.005±0.0011	0.007
Na_2O, %	0.20±0.031	0.19	Free CaO, %	-	1.39

2.2. FILLER

Filler used for preliminary trials was lime filler which is much cheaper than silica fume, also considered as an option. Silica fume was given up because we used cement with larger specific surface and good physical and mechanical properties.

The problem faced during production of self-compacting concrete was achieving the satisfactory properties of green concrete. These requirements could have been satisfied only with use of fillers or some other ingredients to concrete.

The specific surface of used filler by "Granit-Pescar" Ljig was constant and measured 7020 cm^2/g. Filler's bulk density was 2720 kg/m^3. Table 3 shows grain size distribution of the filler.

Table 3. Graine size distribution of filler

Sieve	Pssing %
0.20 mm	99.0
0.09 mm	89.0
0.063 mm	74.0
0.043 mm	57.0

2.3. AGGREGATE

Aggregate used for preliminary trials was a combination of river and crushed aggregate. This combination was necessary to achieve better compacting and better properties of fresh concrete.

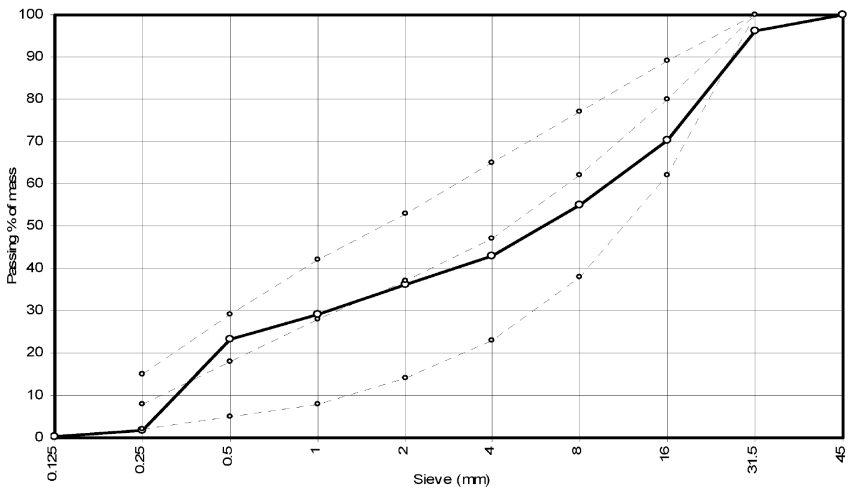

Figure 1. Aggregate grain size distribution

Fraction 0/4 was a river aggregate from the Morava River, while for other fractions crushed aggregate from quarry Sumnik near Raska was used. Crushed aggregate is composed of pure andesite with small percentage of other ingredients and it has very good physical and mechanical properties.

The maximum size of aggregate grains was limited to 16mm because the concrete will be used for very thin elements. Recommendations of eminent world experts for self-compacting concrete were also taken into account while choosing the maximum size of aggregate grains. Figure 1 shows grading curve which was used for all preliminary trials.

2.4. ADMIXTURE

Use of admixtures in production of self-compacting concrete is necessary [1]. It is particularly important that these admixtures belong to concretes with high range water reduction. For preliminary trials two admixtures from two different manufacturers were used.

Two different admixtures were used because they belonged to different generations of admixtures. The first one was from the previous generation of polycarboxylate and the second one was from the last generations of modified polymers. Effects of these two admixtures are very different. Since water-cement ratios in mixes were very low their effects were very important as well as the fact that they were compatible with our cements.

3. PRELIMINARY TRIALS

Preliminary trials were done in the Laboratory for materials testing at IMS Institute in Belgrade from January through April 2007.

Requirements for concrete were prescribed by constructors and referred only to compressive strength of concrete. They were agreed with the experts from IMS Institute who were consulted. These requirements referred to basic properties of fresh concrete [1].

Projected requirements for fresh and hardened concrete are as follows:

- Projected requirements for fresh concrete [2]
    - Slump – flow from 65 to 75 cm
    - L-box H2 / H1 = 0.9 ÷ 1.0
    - V-funnel from 9 to 12 seconds
- Projected requirements for hardened concrete
    - Concrete I - MB 50
    - Concrete II - MB 60

After establishing the projected requirements for fresh and hardened concrete preliminary trials were done. In the first trials we used the experiences from building the bridges in Doboj and Modrica, where concrete with similar properties was used. Still, materials used on those building sites were different so some changes in the mix designs were necessary.

The basic assumption was that the water-cement ratio should not exceed the limit of 0.34 for concrete II, while the limit for concrete I was set higher - at 0.37. It was accepted that the quantity of cement should not exceed 500 kg/m for Concrete II and 450 kg/m for Concrete I. It should be said that some trial mixes were done with more cement than prescribed in order to ascertain the influence of those quantities on concrete strength.
Based on the sieve analysis the grain size distribution curve was accepted according to experience of foreign experts for self-compacting concrete and to our experience during building the said bridges in Doboj and Modrica.

To achieve the properties required for fresh concrete it was necessary to add certain amount of filler. As we said before, because of the economical reasons we decided to use lime filler. Its amount varied depending of the amount of the cement and it was decided to use weights from 550 to 650 $kg/m^{3.}$

Trial mixes for Concrete II were done first. Altogether, there were 15 of them. Table 4 shows the results of achieved properties for some of the mixes while table 5 shows their compressive strengths. It was already mentioned that the trials were done with the cement from Beocin plant. Two trials were done with cement Titan-Kosjeric. Besides the lime filler, trials were done with silica fume as well to ascertain the influence of silica fume on fresh and hardened concrete.

Table 4. Properties of some trial mixes

Cement (kg/m^3)	Sand (kg/m^3)	Coarse aggregate (kg/m^3)	Addition (kg/m3)	w/c	Slump flow (cm)	H2/H1	V-funnel (sek)	Aditiv (kg/m3)
BFC 480[1)]	821	830	70	0.34	68	0.96	12	9.3
BFC 500[1)]	810	842	50	0.34	72	0.93	9	10.1
BFC 530[2)]	807	840	-	0.35	71	0.97	9	10.0
Titan 480	817	835	60	0.34	72	1.0	11	6.0
Titan 500	810	832	50	0.35	76	0.98	8	6.6
BFC500[3)]	820	846	40	0.34	74	1.0	6	6.1

Table 5. Compressive strength of some trial mixes

	Old		
	3 days	7 days	28 days
BFC 480[1)]	60.9	61.7	69.8
BFC 500[1)]	53.2	65.8	72.9
BFC 530[2)]	54.0	63.7	70.7
Titan 480	50.0	64.6	68.3
Titan 500	51.4	66.7	70.2
BFC500[3)]	55.3	57.9	83.2

1) Cement II with speccific surface of 4380 cm^2/g
2) Cement I with sppecific surface of 4720 cm^2/g
3) Like addition was used silicafume

All the trials done and presented in this paper met the projected requirements. Based on the strengths of concrete at 28 days old mix designs were accepted and they were afterwards checked in the new concrete plant on the site.

4. TRIAL MIXES IN SITU

At supervisor's request, the chosen mix designs were tested and confirmed on the building site. Besides the required compressive strength, new requirements concerning properties of hardened concrete appeared. It was necessary to measure shrinkage, creep and modulus of elasticity of concrete. In this paper we give only the results for modulus of elasticity and compressive strength, because the other investigations take time and they are still going on. Only MB 50 (C 40/50) has been confirmed on site so far.

	3 days	7 days	28 days
Compresive strenght (N/mm^2)	48.1	59.3	70.4
Bulk density (kg/m^3)	2385	2370	2365
Modulus of elasticity (N/mm^2)	-	-	42500

5. CONCLUSION

The choice of mixes presented in this paper is only a part of work that is going on at IMS Institute. Based on these investigations the conclusion can be drawn that the use of new materials, especially admixtures of new generations can eventually bring about great cost reductions. Also, more attention should be paid to concretes with high performances whose production in our country is neglected and whose applications could be economically more than justified.

REFERENCE

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PROJEKTOVANJE BETONSKIH MEŠAVINA ZA IZGRANJU AVALSKOG TORNJA

Rezime: *Nove vrste betona u svetskoj praksi su u stalnoj upotrebi. Primena samozbijajućih betona u Srbiji je počela pre nekoliko godina. Za izgradnju Avalskog tornja koristiće se ova vrsta betona. Potrebe za dobrom završnom obradom, kratkim rokovima kao i nižom cenom izgradnje uputili su izvođača na primenu samozbijajućih betona.*
Ključne reči: *samozbijajući beton, visoke čvrstoće, materijali.*