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INFLUENCE OF MINERAL AGGREGATE CONCENTRATION ON THE TECHNOLOGICAL PROPERTIES OF FRESH CONCRETE MIXTURE

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Abstract. The main aim of this research was to investigate how the concentration of mineral aggregate influences the technological properties of concrete mixture such as: slump, flow characteristics and air content, as well as the density of concrete mixture. To sum up, 18 concrete mixture compositions were casted. First six compositions were casted in order to establish the dependence between the ratio of fine aggregate (sand fraction: 0/1 and 0/4) and the technological properties of fresh concrete mixture. Another six compositions were casted in order to investigate the link between course aggregate (gravel, fraction 4/16) concentration and the concrete mixture's technological properties. The last six mixtures were casted in order to test how the amount of fine particles (not exceeding 0.25 mm in diameter) influences the concrete mixture's technological properties.

Keywords: concrete mixture slump, concrete mixture density, flow table test, air content.

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Introduction

The easiest way to increase the workability of concrete mixture is to add extra water. However, the higher w/c ration is, the worse the final properties of the concrete will be. Therefore there are a lot of incentives to improve the workability while keeping the w/c as low as possible or at least at a steady value. This brings us to the aggregates. The workability of concrete mixture could be affected either by the shape and surface texture of the individual particles or the size distribution or grading of the aggregate particles. Round, smooth particles give the best workability, because particles with sharp corners tend to interfere with each other as the concrete flows. The grading of the aggregate determines how efficiently the particles pack together. More distributed in terms of size the aggregate`s particles are, less space between them will be (Thomas, Jennings 2004). Researchers (Burhan, Alshahwany 2010) conducted the test by replacing the sand by 10–50% with the limestone filler. The particles of limestone are much finer compared with the sand and therefore the slump of concrete mixture decreased from 110 mm (reference concrete composition, 0% of limestone filler) to 30 mm (50% of limestone filler). On the other hand, researchers (Uğurlu, Topçu 2003) stressed out that the addition of 7–10% of mineral filler to fine aggregate (0–2 mm) improved the properties of concrete such as: compressive strength and flexural strength. Slump – is one of the most important technological properties of conventional concrete mixture. The relation between technological property (slump) and rheological property (yield stress) of concrete mixture was provided by Wallevik (2006) (Eq. (1)).

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$$S = 300 - 270\frac{\tau_0}{\rho}, \quad (1)$$

where: S – concrete mixture slump, mm;

τ_0 – yield stress of concrete mixture, Pa · s;

ρ – density of concrete mixture, kg/m^3.

According to the firstequation, it is obvious that by increasing yield stress, slump value of concrete mixture decreases.

It was stated by Skripkiūnas (2006) that if the concentration of coarse aggregate increases, the yield stress of concrete mixture decreases proportionally.

Many researchers (Ferraris *et al.* 2001; Zhang, Han 2000; Hu, Wang 2011; Banfill 2011) have discussed how the aggregates of concrete mixture affect concrete rheological properties, but only a few discussed how the concentration of main constituent materials affects it.

Uysal (2012) conducted a flow table test with self-compacting concrete by adding different amount of coarse aggregate – dolomite (769 kg, 384 kg, 307 kg, 230 kg, 154 kg, 77 kg). Test results showed that by increasing amount of coarse aggregate (dolomite), the concrete mixture‘s flow table test‘s results also increases (from 700 to 720 mm).

Researchers (Skripkiūnas *et al.* 2004) conducted a test measuring influence of the granulometry of coarse aggregate on the properties of concrete mixture. They tested a concrete mixture with two different sizes of coarse aggregate (gravel, fraction: 4/8 and 8/16). Researchers came up with the result that by increasing the concentration of 8/16 aggregate and at the same time decreasing 4/8 aggregate (inner-concentration was not changed), yield stress of concrete mixture increased. According to the Eq. (1), if the yield stress increases, the slump rate decreases.

Authors of this article would like to pay attention to the in situ contractors that are casting concrete. The article provides information about how the mixture's technological parameters change in accordance to different concentration of aggregates and fine particles. Researchers (Skripkiūnas, Daukšys 2004) conducted a test regarding the influence of sand particles size and concentration. The results showed that the plastic viscosity of concrete mixture increases using fine aggregate with bigger fraction. Plastic viscosity of concrete mixture was 20 Pa·s by using sand (fraction 0/1) as fine aggregate, on the other hand, when different fraction sand (0/4) was used, plastic viscosity was 55 Pa · s.

The aim of this research is to establish how do the technological parameters (slump, flow characteristics, air content and density of concrete mixture) change in accordance to different fine aggregate (sand, fraction 0/1 and 0/4) inter-concentration, coarse aggregate (gravel, fraction 4/16) concentration and the amount of fine particles (not exceeding 0.25 mm).

1. Methods and materials of the research

JSC "Akmenes cementas" (Lithuania) Portland cement CEM II/A-LL 42.5 R (MA)(A) was used for the test (Table 1).

Table 1. Physical, mechanical properties and chemical composition of Portland cement CEM II/A-LL 42.5 R (MA)(A)

Specific surface area, m^2/kg	410
Normal consistency of cement paste, %	26.5
Volume stability, mm	0.8
Initial setting time, min.	195
Compressive strength after 2 days / after 28 days, MPa	27.1/54.0
Loss on ignition, %	5.05
Insoluble materials, %	–
SO_3, %	2.48
Cl^-, %	0.015
Alkalis, calculated by Na_2O equivalent, %	<0.72

Kvesu quarry sand fr. 0/1 with bulk density 1521 kg/m^3 with fineness module 3.0 and sand fr. 0/4 with bulk density 1711 kg/m^3 with fineness module 2.6 was used for fine aggregate. Gravel fr. 4/16 with bulk density 1657 kg/m^3 was used for coarse aggregate. Granuliometric composition of aggregate is presented in Table 2.

Table 2. Granuliometric composition of aggregate

Length of the sieve's mesh, mm	The amount of passing material, %		
	0/1 fr. sand	0/4 fr. sand	4/16 fr. gravel
32.0	–	–	100.0
16.0	–	–	95.6
8.0	100.0	100.0	34.9
4.0	100.0	97.8	2.9
2.0	99.9	86.3	0.7
1.0	94.8	68.5	0.7
0.500	39.1	37.9	0.7
0.250	3.0	4.9	0.7
0.125	0.3	1.2	0.7
0	0.2	0.1	0.1

Plasticizing admixture based on policarboxile polymers Glenium SKY 628 (BASF Construction Chemicals Italia Spa) was used with density of solution 1.06 g/ml. The total dosage of admixture was 1.2% of cement.

During the research, dry aggregates were used for concrete mixtures. Cement and aggregates were dosed by weight while water and chemical admixture were dosed by volume. Chemical admixtures in the form of solutions were mixed with water and used in preparation of concrete mixtures. Concrete mixtures were mixed for 3 minutes in the laboratory in forced type concrete mixers.

The consistency of concrete mixture was determined by LST EN 12350-2:2009 and LST EN 12350-5:2009, density – by LST EN 12350-6:2009 and air content – by LST EN 12350-7:2009.

Table 3. Composition of concrete mixtures BA1

Materials	The amount of materials for 1m^3 of concrete mixture, kg					
	BA1-0	BA1-1	BA1-2	BA1-3	BA1-4	BA1-5
CEM II/A-LL 42.5 R (MA)(A)	330	330	330	330	330	330
Water	178	178	178	178	178	178
W/C	0.54	0.54	0.54	0.54	0.54	0.54
Sand fraction 0/1	208 11%	303 16%	398 21%	493 26%	588 31%	682 36%
Sand fraction 0/4	701 37%	607 32%	512 27%	417 22%	322 17%	227 12%
Gravel fraction 4/16	986 52%	986 52%	986 52%	986 52%	986 52%	986 52%
Glenium SKY 628	3.96	3.96	3.96	3.96	3.96	3.96

2. Research results

2.1. The influence of fine aggregate (sand, fraction 0/1) quantity to the technological properties of concrete mixture

Concrete mixture composition combined two fractions of fine aggregate: sand 0/1 and 0/4. In order to evaluate the influence of fine aggregate – sand (fraction 0/1) quantity to the technological properties of concrete mixture, the quantity of sand (fraction 0/1) was increased while the quantity of sand (fraction 0/4) was decreased. The quantity of sand (fraction 0/1) was changed from 11 to 36% according to mass in respect to total fine aggregates quantity. The compositions of concrete mixtures (BA1) used in this research are presented in Table 3.

As shown in Figure 1, with the increased quantity of sand (fraction 0/1) from 11 to 36%, the slump of concrete mixture decreased from S4 to S3 class, according to LST EN 12350-2:2009 standard. The concrete mixture's consistency (flow table test) decreased from F4 to F3 class, according to LST EN 12350-5:2009 standard. To sum up, the slump of concrete mixture is reduced about 1.3 times and the consistency according to flow table test is reduced about 1.1 times. If the quantity of fine aggregate is increased, surface area is increased as well. In order to keep the mixture‘s consistency at the same level, the liquid phase must be increased. The highest values of concrete mixture slump (~210 mm) and flow table test (~540 mm) were obtained with the usage of 16% of 0/1 fraction sand.

Density and air content values of concrete mixtures in respect to the quantity of sand (fraction 0/1) are given in the Figure 2. As shown in Figure 2, the density of concrete mixture is decreased if the quantity of fine aggregate (sand, fraction 0/1) is increased from 11 to 36%. On the other hand, the air content is increased. The density of concrete mixture varied from 2390 kg/m^3 to 2320 kg/m^3, while air content varied from 3.8 to 4.9%. The lowest air content rate (3.8%) is obtained with the highest density of concrete mixture (2390 kg/m^3).

It is obvious, that by gradually replacing the fine aggregate (sand, fraction 0/4 and fine module FM = 3.0) with fine aggregate (sand, fraction 0/1

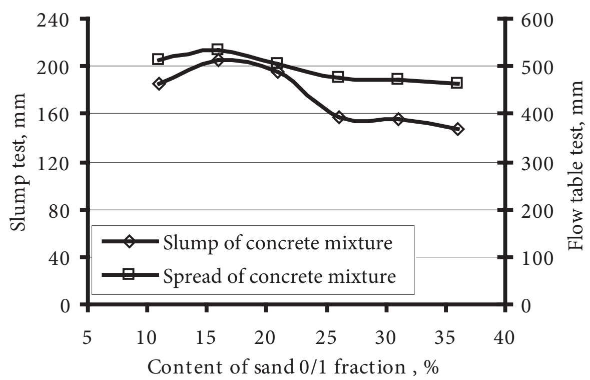

Fig. 1. The changing of concrete mixtures slump and flow table rates in respect to the quantity of fine aggregate (sand, fraction 0/1)

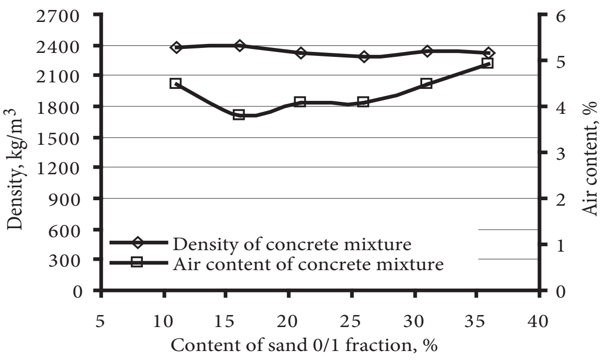

Fig. 2. The changing of concrete mixtures density and air content rates in respect to the quantity of fine aggregate (sand, fraction 0/1)

and fine module FM = 2.6) the air content of concrete mixture is increased and the density of concrete mixture is decreased.

2.2. The influence of course aggregate (gravel, fraction 4/16) quantity on the technological properties of concrete mixture

This laboratory test was based on changing ratio between fine (sand with fractions 0/1 and 0/4) and coarse (gravel, fraction 4/16) aggregates. The concentration (quantity) of coarse aggregate was increased from 22 to 84% in respect to total aggregate's quantity, while at the same time fine aggregate's concentration was decreased. It must be noted, that the inner ratio between fine aggregate (fraction 0/1 and 0/4) was always at the level of 33% and 67% respectively. The compositions of concrete mixtures (BA2) used in this research are presented in Table 4.

As shown in Figure 3, the consistency of concrete mixture measured by slump increased from S1 to S5, according to LST EN 12350-2 standard, and measured by flow table test increased from F1 to F5 according to LST EN 12350-5 standard. The quantity of coarse aggregate was increased from 22 to 82% in respect to total aggregate's amount. The consistency of concrete mixture measured by slump increased about 28 times and measured by flow table test increased about 1.9 times.

It is obvious that the amount of coarse aggregate has the biggest influence on concrete mixture's slump rate. It must be noted, that if the quantity of gravel inside the mixture is increased, the total surface area of aggregates is decreased and therefore the liquid phase required for moistening the aggregate surface decreased as well. The highest slump (270–280 mm) and flow table test rate (~580–630 mm) were obtained when the concentration of coarse aggregate was 72–82%.

Table 4. Composition of concrete mixtures BA2

Mater.	The amount of materials for 1m^3 of concrete mixture, kg						
	BA2-0	BA2-1	BA2-2	BA2-3	BA2-4	BA2-5	BA2-6
CEM II/A-LL 42.5 R (MA)(A)	330	330	330	330	330	330	330
Water	178	178	178	178	178	178	178
W/C	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Sand fraction 0/1	492 33%	429 33%	366 33%	303 16%	240 33%	177 33%	114 33%
Sand fraction 0/4	986 67%	860 67%	733 67%	607 32%	480 67%	354 67%	228 67%
Gravel fraction 4/16	417 22%	607 32%	796 42%	986 52%	1175 62%	1365 72%	1554 82%
Glenium SKY 628	3.96	3.96	3.96	3.96	3.96	3.96	3.96

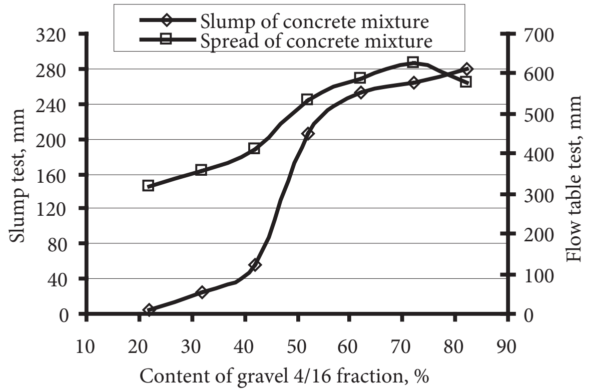

Fig. 3. The changing of concrete mixtures slump and flow table test rates in respect to the quantity of coarse aggregate (gravel, fraction 4/16)

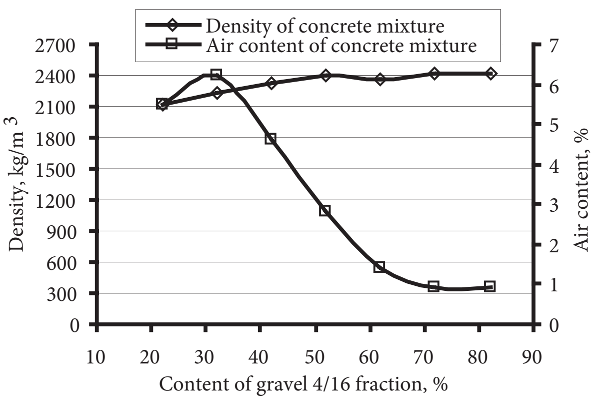

Fig. 4. The change of concrete mixtures density and air content rates depending of the amount of gravel fraction 4/16

Density and air content values of concrete mixtures in respect to the quantity of coarse aggregate are given at Figure 4. As shown in Figure 4, the density of concrete mixture is increased from 2130 to 2420 kg/m^3 while the quantity of coarse aggregate (gravel, fraction 4/16) is increased from 22 to 82%. On the other hand, the air content decreased from 5.5 to 0.9%. It must be noted that if the coarse aggregate's concentration is 32%, the air content is increased from 5.5 to 6.2%.

The further increase of coarse aggregate resulted in noticeable decrease of air content.

2.3. The influence of fine particles (not exceeding 0.25 mm) quantity to the technological properties of concrete mixture

The total quantity of fine particles combined particles from sand and cement with the certain diameter. In order to investigate the influence of fine particles (not exceeding 0.25 mm) quantity to the technological properties of concrete mixture, the amount of cement was increased. The quantity of fine aggregate (sand, fraction 0/1 and 0/4) was decreased respectively. It must be noted that the concentration of fine aggregate (fraction 0/1) was 33% and the concentration of fine aggregate (fraction 0/4) was 67%.

Table 5. Composition of concrete mixtures BA3

Materials	The amount of materials for 1m^3 of concrete mixture, kg						
	BA3-0	BA3-1	BA3-2	BA3-3	BA3-4	BA3-5	BA3-6
CEM II/A-LL 42.5 R (MA)(A)	180	230	280	330	380	430	480
Water	178	178	178	178	178	178	178
W/C	0.99	0.77	0.64	0.54	0.47	0.41	0.37
Sand fraction 0/1	353 33%	336 33%	320 33%	303 33%	286 33%	270 33%	253 33%
Sand fraction 0/4	707 67%	674 67%	640 67%	607 67%	574 67%	540 67%	507 67%
Gravel fraction 4/16	985 52%	985 52%	985 52%	985 52%	985 52%	985 52%	985 52%
Glenium SKY 628	3.96	3.96	3.96	3.96	3.96	3.96	3.96

The concentration of coarse aggregate (gravel, fraction 4/16) was 52%. The quantity of fine particles was changed from 225 to 512 kg to one cubic meter of concrete mixture. The quantity of plasticizing admixture was 3.96 liters to one cubic meter of concrete mixture. The compositions of concrete mixtures (BA3) used in this research are presented in Table 5.

The consistency by slump and flow table tests of the concrete mixtures in respect to the amount of fine particles is shown in Figure 5.

As shown in Figure 5, the increase of fine particles (not exceeding 0.25 mm) quantity from 225 to 512 kg to one cubic meter of concrete mixture resulted in change of slump from 20 to 220 mm and of flow table test rate from 370 to 540 mm. The consistency of concrete mixture measured by slump changed from S1 and by flow table test - from F2 to F4. The slump of concrete mixture increased around 11 times while the quantity of fine particles increased from 225 to 417 kg to one cubic meter of concrete mixture. The further increase of fine particles over the 417 kg resulted in reduced slump from S5 to S4. The consistency of concrete mixture was also influenced by plasticizing admixture quantity. During the research, the quantity of plasticizing admixture was kept constant. With the minimum amount of cement (180 kg to 1 m^3 of con-

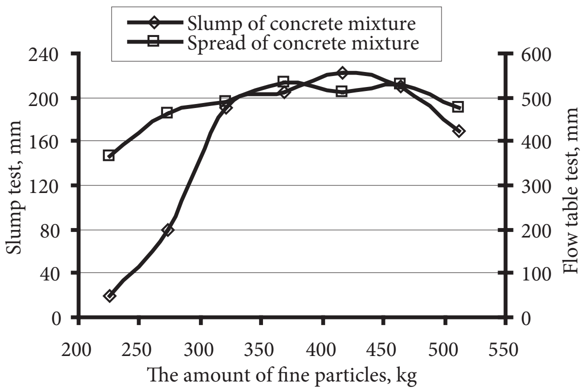

Fig. 5. The changing of concrete mixtures slump and flow table test rates in respect to the amount of fine particles

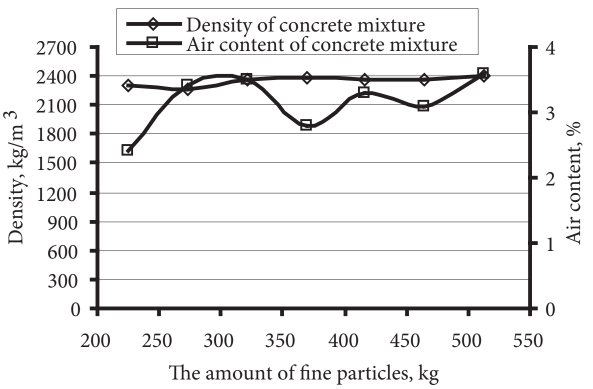

Fig.6. The change of concrete mixtures density and air content rates depending of the amount of fine particles

crete mixture), the quantity of plasticizing admixture was 2.2%. Further increase of cement quantity resulted in the reduction of plasticizing admixture.

Density and air content values of concrete mixtures in respect to the quantity of fine particles are given in Figure 6. As shown in Figure 6, the increase of fine particles quantity from 225 to 512 kg to 1m^3 of concrete mixture resulted in the increase of mixture‘s density from 2260 to 2390 kg/m^3. The air content varied between 2.4 and 3.6%. The lowest density of concrete mixture (2260 kg/m^3) was obtained when the quantity of fine particles was 273 kg to 1 m^3 of concrete mixture.

The further increase of fine particles quantity to 512 kg resulted in the increase of concrete mixture density by 1.06 times. The lowest rate of air content (2.4%) is obtained when the fine particles quantity was 225 kg to 1 m^3 of concrete mixture. The further increase of fine particles over the 512 kg resulted in air content increase from 2.8 to 3.6%.

Conclusions

1. The change of fine aggregate (sand, fraction 0/1) concentration from 11 to 36% in respect to total amount of aggregates resulted in reduction of concrete mixture slump and flow table test rate from S4 to S3 and from F4 to F3 respectively. It must be noted that the finer the sand is, the higher air content rate and the lower density of concrete mixture is obtained.
2. The increase of coarse aggregate (gravel, fraction 4/16) concentration from 22 to 82% resulted in bigger consistency measured by slump and flow from S1 to S5 and from F1 to F6 respectively. The air content of concrete mixture reduced significantly (about 6.9 times). On the other hand, the density of concrete mixture increased about 1.1 times.
3. The change of fine particles (not exceeding 0.25 mm) quantity from 225 to 512 kg to 1 m^3 concrete mixture resulted in alteration of mixture slump and flow table rate from S1 to S5 and from F2 to F4 respectively. The density of concrete mixture increased 1.06 times. What is more, the air content increased 1.5 times.

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MINERALINIŲ UŽPILDŲ KONCENTRACIJOS ĮTAKA ŠVIEŽIO BETONO MIŠINIO TECHNOLOGINĖMS SAVYBĖMS

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Santrauka. Pagrindinis šio tyrimo tikslas – nustatyti, kaip mineralinių užpildų koncentracija veikia technologines betono mišinio savybes: slankumą, sklidumą, oro kiekį ir mišinio tankį. Iš viso buvo tirta 18 skirtingų betono mišinio sudėčių. Pirmosios šešios sudėtys buvo analizuojamos siekiant nustatyti priklausomybę tarp smulkaus užpildo koncentracijos (smėlio frakcijos: 0/1 bei 0/4) ir technologinių betono mišinio savybių. Kitos šešios sudėtys buvo analizuojamos siekiant rasti priklausomybę tarp stambaus užpildo koncentracijos (žvirgždo frakcija 4/16) ir technologinių betono mišinio savybių. Paskutinės šešios betono mišinio sudėtys buvo analizuojamos siekiant nustatyti smulkiųjų dalelių, kurių skersmuo neviršija 0,25 mm, kiekio įtaką technologinėms betono mišinio savybėms.

Reikšminiai žodžiai: betono mišinio slankumas, betono mišinio tankis, sklidumo bandymas, oro kiekis.

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