VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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INFLUENCE OF THE FRACTIONATED CONCRETE WASTE AND PLASTICIZING ADMIXTURE ON THE PROPERTIES OF CEMENT CONCRETE

SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
MATERIALS ENGINEERING (08T)

VGTU LEIDYKLA
Vilnius TECHNIKA 2013

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2009–2013.

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Materials Engineering in the Senate Hall of Vilnius Gediminas Technical University at 10 a. m. on 14 January 2014.

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The summary of the doctoral dissertation was distributed on 13 December 2013.

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania).

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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FRAKCIONUOTŲ BETONO ATLIEKŲ IR PLASTIFIKUOJANČIOS ĮMAIŠOS POVEIKIS CEMENTBETONIO SAVYBĖMS

DAKTARO DISERTACIJOS SANTRAUKA

TECHNOLOGIJOS MOKSLAI,
MEDŽIAGŲ INŽINERIJA (08T)

LEIDYKLA
Vilnius TECHNIKA 2013

Disertacija rengta 2009–2013 metais Vilniaus Gedimino technikos universitete.
Mokslinis vadovas
doc. dr. Ramunė ŽURAUSKIENĖ (Vilniaus Gedimino technikos universitetas, technologijos mokslai, medžiagų inžinerija – 08T).
Disertacija ginama Vilniaus Gedimino technikos universiteto Medžiagų inžinerijos mokslo krypties taryboje:
Pirmininkas
dr. Valentin ANTONOVIČ (Vilniaus Gedimino technikos universitetas, technologijos mokslai, medžiagų inžinerija – 08T).
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Disertacija bus ginama viešame Medžiagų inžinerijos mokslo krypties tarybos posėdyje 2014 m. sausio 14 d. 10 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.
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Disertacijos santrauka išsiuntinėta 2013 m. gruodžio 13 d.
Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva).
VGTU leidyklos „Technika“ 2205-M mokslo literatūros knyga.

Introduction

Problem formulation. Construction waste reprocessing and management issues are topical nowadays, because every day a lot of construction waste is created in construction sites during reconstruction and demolition of old buildings. A large part of this waste is transported to the dumps, it does not decompose and does pollute the environment. Currently in Lithuania, the application of concrete waste products offered in the market is limited to their utilisation in the construction of roads or pathways. Still, concrete waste can be utilised in concrete production as coarse or fine aggregate for the manufacturing of certain construction products without using non-renewable natural materials. Considering that resources of coarse aggregates are limited in Lithuania and concrete waste utilisation is poorly developed, this problem becomes topical.

Research topicality. The problems of the reprocessing of concrete waste are being tackled intensively throughout the world. Many scientists, who have analysed the influence of concrete waste on the properties of hardened concrete, state that waste materials worsen properties of concrete construction products, i.e. concrete's strength decreases, and water absorption increases. Currently scientific researches on the topic discussed are targeted to the search of suitable additives and admixtures as well as to the investigations determining the rational utilisation of concrete waste for the production of high quality new products. Practically, in Lithuania concrete waste and polycarboxylate superplasticizer is not utilised in concrete production. Nowadays concrete waste is used more often for roads construction. In order to develop the technology for the utilisation of concrete waste in concrete mixtures, it is necessary to carry out scientific investigations on the selection of suitable compositions of concrete mixtures or on the search of additives and admixtures that could improve concrete's physical and mechanical properties. In such a way concrete waste could be utilised in the technological cycle of the manufacturing of new products.

Research object. Research object is concrete waste and modified cement concrete with concrete waste.

Research objective. To determine the influence of dispersed as well as fractionated concrete waste and plasticising admixtures on the properties and structure of cement concrete.

Research tasks

1. To analyse the properties of concrete waste, i.e. to determine physical and mechanical properties of waste of various coarseness as well as the granulometric composition.
2. Analyse the influence of concrete waste on the hydration of Portland cement.
3. To determine the influence of fractionated concrete waste on physical and mechanical properties of the hardened concrete.
4. To determine concrete's composition, allowing us to replace as large as possible amount of natural coarse aggregate and sand with the crushed concrete waste by using special admixture improving the properties of concrete produced.
5. To determine the physical and mechanical properties as well as durability (according to frost resistance and alkali corrosion) of the concrete with dispersed and fractionated concrete waste and polycarboxylate superplasticizer admixture.

Research methodology. The main properties of the raw materials and hardened concrete were determined by employing standard investigation methodologies and the ones described in the scientific literature. Contact area between concrete waste aggregates and newly formed cement stone was investigated with raster electronic microscope by employing navigation system.

Scientific novelty

1. The methodology for the production of high quality products by utilising fractionated concrete waste is proposed. These waste materials have to be dispersed as well as fractionated and then utilised as coarse and fine aggregates. In addition, these waste materials can be combined with fine natural sand and the concrete with analogous properties can be produced, or it is possible to use admixture of polycarboxylate superplasticizer allowing us to reach density, absorption and compressive strength values close to the ones of the concrete with natural aggregates.
2. The influence of concrete waste and concrete waste with the admixture of polycarboxylate superplasticizer on cement hydration process was analysed. Cement hydration processes depend on the amount of concrete waste. In addition, values of these processes decrease due to polycarboxylate superplasticizer admixture, when it is used together with the aggregates from the crushed concrete waste.

3. Durability (according to the resistance to frost and alkali corrosion) of the concrete with crushed concrete waste as well as the concrete with crushed concrete waste and admixture was investigated. After plasticising admixture is introduced into the concrete mixture, mass loss decrease during the determination of frost resistance, calculated forecasted exploitational frost resistance increases and concrete's expansion in alkali environment decreases.
4. Contact area between aggregate, prepared by crushing concrete waste, and newly formed matrix of cement stone was investigated. Admixture of polycarboxylate superplasticizer utilised during the research visually merges the contact area between the concrete waste aggregate and concrete's mortar part.

Practical value. The usage of concrete waste for the manufacturing of new products allows us to resolve issues related to waste utilisation and saving of natural resources. These factors contribute to the possibility to utilise a large amount of waste materials in the market of concrete products. In future, the products, manufactured from such concrete, could replace a part of currently manufactured products and decrease utilisation rate of natural resources.

Defended propositions

1. When suitable compositions of the concrete mixtures are selected and when quality characteristics of the required components are obeyed, concrete waste can be returned to the technological cycle of the manufacturing of concrete products by serving as coarse and fine aggregates.
2. Polycarboxylate superplasticizer improves exploitational properties of the concrete, where coarse and fine aggregates were replaced by concrete waste, as well as adhesion between newly formed matrix of cement stone and aggregate from concrete waste.

Structure of dissertation. Dissertation is composed from the introduction, three chapters, general conclusions, lists of the reference literature and publications of dissertation author.

The total scope of dissertation – 121 pages, 5 numbered equations employed, 60 pictures and 18 tables are used in the textual part. 120 references were included in the dissertation.

1. Concrete waste and the use of it. Processes happening during cement hydration

A large amount of concrete waste is created worldwide. This waste is created during the construction, restoration, repair or demolition of the buildings. Spoilage of construction products is also considered as concrete waste. Concrete waste is hardly decomposing material, and it occupies large areas when stored in the dumps. In respect to the ecological safety and in order to save natural resources, concrete waste can be utilised for the production of the high quality products by returning this waste to the production technological cycle.

Since the origin of coarse and fine aggregates may vary, coarse and fine aggregates can be replaced by the aggregates produced from the crushed concrete waste. Literature analysis shows that, when part of natural aggregates is replaced by concrete waste, strength, density of the hardened concrete decreases, and absorption increases. In order to utilise large amounts of concrete waste as aggregates and replace overall concrete aggregates, it is necessary to adjust concrete compositions, seek for various additives, admixtures improving the properties of cement concrete with concrete waste.

2. Raw materials, investigation methodologies and concrete compositions

Portland cement CEM II/A-LL 42.5 N produced by SC "Akmenės cementas". Natural breakstone and crushed concrete waste were utilised as coarse and fine aggregates. The size of the particles of coarse aggregate is 4–16 mm, fine aggregate – 0.125–4 mm. Aggregate from concrete waste is composed from the several particle types: natural aggregate that split during the crushing and does not have mortar part particles adhered around; natural aggregate and mortar part, which was left uncrushed during the crushing process, adhered on one or several sides; as well as particles formed only from the crushed mortar part. The main characteristics of coarse and fine aggregates are provided in Table 1. Filler aggregate obtained by sieving out the crushed concrete waste. Size of the particles of the filler aggregate is smaller than 0.125 mm, main characteristics are as follows: bulk density – 0.96 g/cm³, particles' density – 2.50 g/cm³, specific surface area – 2910 cm²/g. Admixtures: vinyl acetate and ethylene with higher vinylesters copolymer, stabilised with mineral additives and protective colloid (WACKER POLYMERS "VINNAPAS 7031 H"), vinyl acetate and ethylene copolymer, stabilised with mineral additives and protective colloid (WACKER POLYMERS "VINNAPAS 5046 T"), vinyl acetate copolymer ("ELOTEX FX2330"), synthetic copolymer with large molecular mass ("RheoMATRIX"); polycarboxylate superplasticizer (BASF "GLENIUM SKY 527").

Table 1. Characteristics of coarse and fine aggregate

Aggregate	Bulk density, g/cm³	Particles' density, g/cm³	Hollowness, %	Water absorption after 48 hours, %	Cleavage index,%
Gravel 4/16	1.43	2.60	42	1.80	14
Concrete waste 4/16	1.25	2.30	46	7.80	34
Natural sand 0.125/4	1.63	2.43	35	–	–
Concrete waste 0.125/4	1.24	2.33	45	–	–

The main properties of the raw materials and hardened concrete were determined by employing standard investigation methodologies and the ones described in the scientific literature. For the investigation of the structure of raw materials X-ray analysis, raster electronic microscope analysis methodologies were employed. The recognition of samples cut was implemented and phases' areas were calculated. Contact area was investigated with the raster electronic microscope by employing navigation system. During the investigation of the influence of concrete waste on the hardening of concrete mixture, temperature measurements of the exothermic effect, electric conductivity, calorimetric investigations of Portland cement paste with waste materials and additives were implemented.

4 concrete mixtures were prepared with the markings NS0, NS1, NS2, NS3. In NS0 and NS3 mixtures gravel was utilised as coarse aggregate, NS1 – mixture of gravel and crushed concrete waste, NS2 – only crushed concrete waste. In mixture NS3 8% of cement mass was replaced by filler aggregate.

During investigations the normal concrete with complex fine aggregate was analysed as well. 4 concrete mixtures were prepared with the markings DK, D40, D60, D80. The largest amount of the crushed particles obtained from concrete waste was used in mixture D80, and this amount was equal to 80% comparing to the mass of fine aggregate. The lowest amount of crushed particles of concrete waste was in concrete mixture D40 – 40%, and in D60 mixture – 60%.

After the analysis of the references and after the investigations with other admixtures, one admixture – polycarboxylate superplasticizer admixture Glenium Sky 527 was selected. 7 concrete mixtures were prepared with the markings GK, TB1, TB2, TB3, TM1, TM2, TM3. Compositions of concrete mixtures are provided in Table 2.

Table 2. Compositions of the concrete with concrete waste and admixture of polycarboxylate superplasticizer for 1 m³ of mixture

Marking of the batch	Amount of components								W/C	Slumping, cm
	Cement, kg	Coarse aggregate (4/16), kg		Fine aggregate (0.125/4), kg		Filler aggregate (0/0.125), kg	Admixture of polycarboxylate superplasticizer, kg	Water, l		
		Gravel	Concrete waste	Natural sand	Concrete waste					
GK	551	667	–	948	–	–	–	235	0.43	3.0
TB1	551	–	667	–	948	–	–	287	0.52	3.0
TB2	551	–	667	–	948	–	4.41 (0.8%)	224	0.41	3.5
TB3	551	–	667	–	948	–	7.71(1.4%)	207	0.38	3.0
TM1	551	–	667	–	888	62	–	287	0.52	2.5
TM2	551	–	667	–	888	62	4.41 (0.8%)	274	0.50	3.0
TM3	551	–	667	–	888	62	7.71(1.4%)	269	0.49	3.5

All concrete compositions were selected in accordance with the characteristics of raw materials, by applying computational - experimental methodology and employing software suite “AGbetonas”. During calculation of concrete compositions, the slumping class (3±0.5 cm) of the concrete mixtures was selected to correspond to S1 class, and compressive strength of the hardened concrete – to C30/37 class.

3. Researches of the influence of concrete waste and plasticising admixture on the cement hydration and the properties of concrete

Considering the influence of concrete waste on cement hydration process, investigations, showing how filler aggregate changes water demand, were implemented. 5%, 10%, 15%, 20%, 25% and 30% of filler aggregate was introduced to binder mass. Investigation results showed that the particles of filler aggregate increase water demand required to prepare normal cement paste and increases initial set of Portland cement. Water demand increases proportionally to the amount of filler aggregate introduced, and reaches 29.5%. Initial set starts after 290 min, when the amount of filler aggregate is 30%. The results of calorimetric investigations showed that replacement of 15% of filler aggregate almost does not have a large influence on heat amount dissipated, and the amount of heat dissipated from filler aggregate is very low. Electric conductivity decrease in the suspension with filler aggregate shows that ion exchange between particles and suspension's liquid phase is very low.

During the investigation of the influence of filler aggregate on cement's strength properties, grouts, where 0%, 5%, 10%, 20%, 30% part of Portland cement was replaced by filler aggregate, were prepared. After the identifying of bending and compressive strengths of cement samples, it can be noticed that, depending on the amount of filler aggregate in cement composition, bending and compressive strengths decrease. Bending strength decreases by 17% and compressive strength by 43% when the largest amount of filler aggregate is introduced in the mass, comparing to the samples with no filler aggregate.

When the investigation of the influence of crushed concrete waste on concrete's properties (compositions NS0–NS3) was carried out, composite phase areas were analysed and calculated during the macrostructure analysis. It can be sated that in the mixtures, prepared with crushed concrete waste, it is distributed evenly in overall concrete mass. However, several problems are encountered: some amount of air is sucked in concrete mixture together with concrete crumbs and remains during the compaction. Concrete particles, created during the crushing, and having fractures as well as cracks are passed into the mixtures. This negatively influences the strength, absorption and other hardened concrete properties.

After the estimation of compressive strength after 7 and 28 days of hardening, it can be stated that compressive strength decreases with the increase of the crushed concrete waste in mixture. In case all aggregates are replaced by the crushed concrete waste, compressive strength decreases by 16–18%, when compared with compressive strength of the reference samples. The decrease of compressive strength can be explained by the weakened bond between the crushed concrete waste aggregate and concrete's hardened mortar part.

Calculated values of the predicted exploitational frost resistance allows us to state, that the largest predicted frost resistance belongs to the concrete samples which were prepared by utilising natural aggregates (NS0). When the crushed concrete waste was utilised (NS1, NS2) – the calculated values are lower. The same stands for the samples with filler aggregate (NS3). The analysis of frost resistance of concrete samples by employing direct method in accordance with the alternative CF/CDF testing methodology shows that mass loss in concrete samples, where a part of coarse aggregate was replaced by the crushed concrete aggregate, and the samples, where crushed concrete waste replaced all aggregates, was the largest. However, mass loss did not reach the maximal values. Samples' frost resistance results show that mass loss in no sample reached the maximal allowed value – 15 g/dm².

In case complex fine aggregate is utilised in concrete mixtures, calorimetric investigations indicate, that in fine fraction, when the amount of concrete waste increases, Tmax of exothermic process decreases, and the rate of reaching this temperature increases. Absorption results of the hardened concrete with complex fine aggregate show that the highest samples' absorption, reaching 7–8%, was achieved after soaking of D80 samples, and the lowest absorption – 4–5% and 5–6% was achieved for D40 and D60 samples. The estimated compressive strength of concrete samples indicates that compression strength depends on the amount of crushed concrete waste in the samples. The suitable composition of complex fine aggregate is as follows: 40% of crushed concrete waste (0.125/4) and 60% of fine sand (0/1). When discussing the calculated forecasted exploitational frost resistance of the examples and testing methodology, estimated through experiments according to CF/CDF, it can be stated that, when the amount of fine natural sand is increase in concrete mixtures, mass loss and cracks in contact area decrease, as well as the calculated number of cycles increases.

The selected 4 polymeric admixtures, which amounts of 1% and 2% were added to the concrete mixtures, have not created a possitive influence on the major part of parameters of the concrete where the crushed concrete waste was utilised for the mixtures: water demand, required to prepare the concrete mixture corresponding to slumping class S1 has not changed; 1% of the admixture, decreased absorption of the hardened samples, however, 2% had no large influence on the decrease of sample's absorption; admixtures have decreased the compressive strength, but samples' dnsity was identical to the one of reference samples. Due to these reasons the another polymeric admixture was selected and analysed in the research – polycarboxylate superplasticizer.

After the introduction of 0.8% and 1.4% of polycarboxylate superplasticizer admixture into the Portland cement, it was identified that this admixture lowers V/Cn and increases cement's initial set. Results of the investigations of cement's hydration process showed that the admixture slows down this process. Admixture's influence on the electric conductivity of cement suspension allows us to conclude that polycarboxylate superplasticizer admixture decreases ion release rate, and the maximal value of electric conductivity was reached only after 340 min. Whereas the maximal value of electric conductivity of the cement without admixture was reached already within 200 min after the beginning of mixing with water. During the investigation of the process of exothermic reaction it was determined that the admixture used extends the time period required to reach the maximal temperature.

Influence of polycarboxylate superplasticizer admixture on physical and mechanical properties of concrete with crushed concrete waste was determined (compositions are shown in Table 2). According to the results of compressive strength obtained after 7 and 28 days of hardening (Fig.1 a)), it can be stated that concrete's compressive strength depends on the origin, quality of the aggregates and on the amount of admixture utilised.

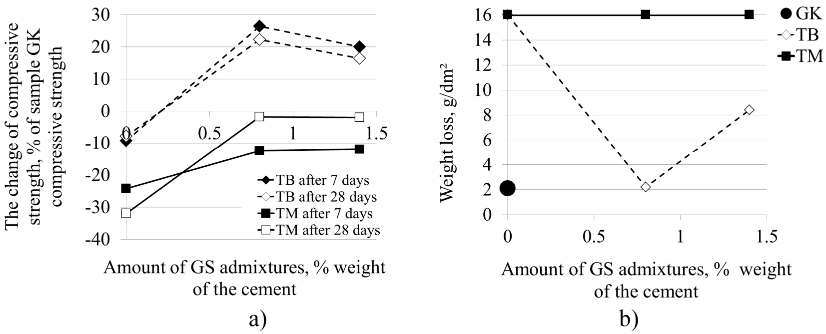
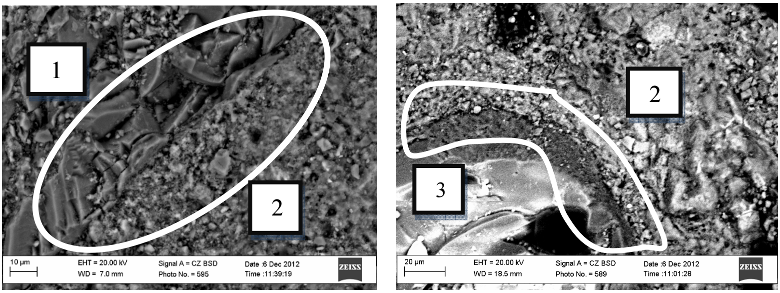


Fig. 1. The dependence of samples' properties on the characteristics of coarse and fine aggregates and the amount of polycarboxylate superplasticizer admixture: a – on the compressive strength; b – on mass loss after 56 test cycles

After the comparison of compressive characteristics of TB1–TB3 and TM1–TM3 samples, it was noticed that the larger amount of admixture almost does not influence samples' compressive strength. Samples' mass loss identified during the cooling (Fig. 1 b)) does not reach the allowed maximal limits, but are close to mass loss of the reference sample GK. However, small cracks appeared in cement matrix and in some locations of contact area between the aggregates of crushed concrete waste and concrete's hardened mortar part. It can be noticed that admixture positively influences the concrete analysed, where aggregates from the crushed concrete waste were fractionated.

Considering the expansion results obtained during the alkali corrosion process, it can be assumed that regardless the utilisation of polycarboxylate superplasticizer, in concretes where the aggregates from the crushed concrete waste are utilised, the outcome of alkali corrosion is minimal.

After the images, obtained during the investigation of contact area between natural aggregate and concrete's mortar part, were analysed with raster electronic microscope (Fig. 2 a)), it can be noticed that aggregate has a good adhesion with the hardened mortar part. There are no cracks between natural aggregate and hardened mortar part. However, it was noticed that the aggregate from concrete waste has weak adhesion with cement stone, micro-cracks and splits (Fig. 2 b)) are created in their contact area. These micro-cracks and splits separate the main concrete components, and this results in weakening of the adhesion of components.



a) b)

Fig. 2. Contact area between the concrete mortar part and aggregate: a – sample GK; b – sample TB1; 1 – natural aggregate; 2 – hardened mortar part; 3 – aggregate, obtained after the crushing of concrete waste

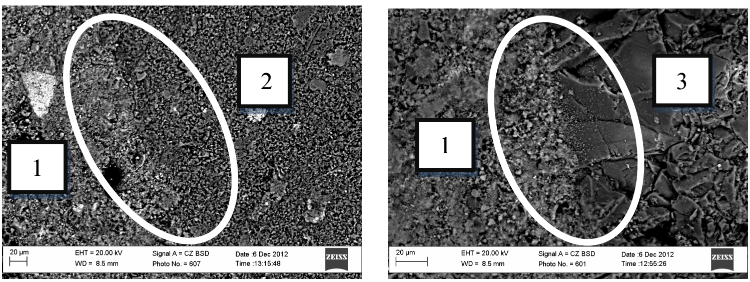


Fig. 3. Contact area between hardened mortar part and aggregate from the crushed concrete waste, when polycarboxylate superplasticizer admixture was utilised in the concrete (sample TB2): 1 – hardened concrete's mortar part; 2 – aggregate from the crushed concrete waste (crushed mortar part); 3 – aggregate from the crushed concrete waste (part of natural aggregate)

The influence of polycarboxylate superplasticizer on samples' structure is shown in Fig. 3. It is seen that the aggregates from the crushed concrete waste have a good adhesion to the mortar part, no splits and cracks are created around the aggregate.

This indicates that polycarboxylate superplasticizer admixture positively influences the matrix of cement concrete prepared, improves the adhesion between the aggregate, prepared after the crumbing of the crushed concrete waste, and concrete's mortar part.

General conclusions

1. Literature analysis suggests that density and strength of the concrete, where aggregates from the crushed concrete waste were utilised, decrease depending on the characteristics of concrete waste introduced into the mixture.
2. After the implementation of investigations it can be stated as follows:
   - it is necessary to fractionate the crushed concrete waste by separating its particles with the diameter smaller that 0.125 mm, because they change the structure of the hardened concrete by filling the gaps between the coarse aggregates and by increasing the distance between these aggregates that form concrete's "frame" at the same time. Concrete's waste decreases the compressive strength of the hardened concrete by 25–32%, density – by 8–11 % as well as increases absorption by 31–39%, when compared to the concrete prepared by utilising natural aggregates, and decreases the compressive strength by 21–26%, density – by 3–5% as well as increases absorption by 7–9%, when compared to the concrete prepared by utilising fractionated (0.125/4 and 4/16) concrete waste;
   - compressive strength of the concrete, where coarse (4–16 mm) and fine (0.125–4 mm) aggregates from the crushed concrete waste were utilised in concrete's composition, decreases by by 5–8%, density – by 8–18%, forecasted exploitational frost resistance – by 19–28%. At the same time absorption increases by almost two times due to the change of concrete's structure and properties of the fractionated concrete waste utilised, when compared to the properties of natural aggregates (strength of waste materials is 2.5 times smaller, and absorption is larger);
   - without worsening the properties of concrete, in concrete mixtures it is possible to utilise fine aggregates of the crushed concrete waste (0.125–4 mm) by combining them together with fine (module of coarseness is up to 1) natural sand with the ratio of

40:60. Fine aggregate mixture of such composition ensures the compacted structure of the concrete and best values of the parameters of hardened concrete.

3. Polycarboxylate superplasticizer admixture (0.8% of cement mass) influences positively the properties of concrete, composed from coarse (4/16 mm) and fine (0.125–4 mm) aggregates, prepared from the crushed concrete waste:
   - decreases water demand, required to prepare the concrete mixture of the required consistence, by 22–24%;
   - increases the time required to reach te maximal temperature of exothermic effect up to 2 h;
   - decreases water absorption by 15–17% and increases density of concrete samples by 4–6%;
   - increases compressive strength of hardened concrete up to 1.5 times;
   - 48–50% increases samples estimated forecasted exploitational frost resistance, while the loss of mass after 56 cooling and heating cycles does not pass the highest allowed limits.

   The positive influence of polycarboxylate superplasticizer admixture can be explained by the fact that this admixture lowers the tensions of the surface of liquid phase and better adhesion of components is ensured in this way. In addition, the admixture covers the aggregate from the crushed concrete waste with film protecting the aggregate from absorbing the larger amounts of water during the mixing. Then water, required for cement binding, is not created, no splits are created in the contact area between cracks and components. In this way the closer contact between concrete's components and the compaction of concrete structure are ensured.
4. Concrete with the crushed concrete waste as well as the concrete with the crushed concrete waste and polycarboxylate superplasticizer admixture are more resistant to the influence of alkali environment due to possibly smaller amount of the reactive SiO_2 than the concrete samples with natural aggregates.
5. Investigations showed that the fractionated concrete waste in large amounts can be utilised in the compositions of cement concrete, ensuring the physical and mechanical properties of the hardened concrete close to the ones of the concrete where natural aggregates are used. This allows to save non-renewable natural resources as well as to reduce the dumps of concrete waste.

List of Publisched Works on the Topic of the Dissertation
In the reviewed scientific periodical publications

Finoženok, O.; Žurauskienė, R.; Žurauskas, R. 2013. The influence of crushed concrete demolition waste aggregates on the hardening process of concrete mixtures. *Materials science*. Kaunas: Technologija, vol. 19, no.1. p. 96–102. ISSN 1392-1320. (Thomson ISI Web of Science).

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Finoženok, O.; Vanagel, B.; Žurauskienė, R.; Žurauskas, R. 2013. Composition selection and analysis of concrete produced by utilising sand from crushed concrete waste. Construction Science. Warsaw: Versita. Vol. 14, p. 26–31. ISSN 1407-7329 (INSPEC).

In the other editions

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Gratitude

I'm thankful to scientific supervisor Assoc Prof Dr Ramunė Žurauskienė, also special grateful to Prof Dr Albinas Gailius for counseling on dissertation subjects, support and felicitous comments.

FRAKCIONUOTŲ BETONO ATLIEKŲ IR PLASTIFIKUOJANČIOS ĮMAIŠOS POVEIKIS CEMENTBETONIO SAVYBĖMS

Problemos formulavimas. Statybinių atliekų perdirbimo ir tvarkymo klausimai aktualūs šiais laikais, nes statybos aikštelėse kiekvieną dieną rekonstruojant ar griaunant senus pastatus, atsiranda daug betono atliekų, kurių didelė dalis patenka į sąvartynus, jos neyra ir teršia aplinką. Šiuo metu tiekiamų į rinką betono atliekų produktų pritaikymas mūsų šalyje apsiriboja jų naudojimu kelių tiesimui arba įrengiant takus. Tačiau betono atliekas būtų galima panaudoti betono gamyboje, kaip stambųjį arba smulkųjį užpildą, kai kuriems statybos dirbiniams gaminti. Žinant, kad stambiųjų gamtinių užpildų ištekliai Lietuvoje yra riboti, o betono atliekų panaudojimas yra nepakankamas, ši problema tampa labai aktuali.

Darbo aktualumas. Pasaulyje betono atliekų perdirbimo ir panaudojimo problemos intensyviai sprendžiamos. Daugelis mokslininkų ištyrę betono atliekų poveikį sukietėjusio betono savybėms teigia, kad atliekos pablogina statybos produktų iš betono savybes, tai yra, betono stipris sumažėja, o vandens įmirkis padidėja. Moksliniai tyrimai nagrinėjamoje temoje šiuo metu yra nukreipti į tinkamų priedų ir įmaišų paieškas ir į tyrimus, kaip racionaliai panaudoti betono atliekas naujų kokybiškų dirbinių gamyboje. Lietuvoje tokių darbų, kai betono gamyboje būtų naudojamos trupintos betono atliekos ir polikarboksilatinis superplastiklis, praktiškai nebuvo vykdoma, o betono atliekos šiuo metu dažniausiai naudojamos kelių tiesimui. Norint betono mišiniuose naudoti didelį kiekį betono atliekų, reikia atlikti mokslinius tyrimus, parenkant tinkamiausias betono mišinių sudėtis arba ieškoti priedų bei įmaišų, kurie pagerintų betono fizikines bei mechanines savybes. Tokiu būdu betono atliekos galėtų būti panaudotos naujų dirbinių gamybos technologiniame cikle.

Tyrimų objektas. Darbo tyrimo objektas yra betono atliekos ir cementbetonis su betono atliekomis.

Darbo tikslas. Nustatyti disperguotų ir frakcionuotų betono atliekų bei plastifikuojančios įmaišos poveikį cementbetonio savybėms ir struktūrai.

Darbo uždaviniai

1. Ištirti betono atliekų savybes – nustatyti įvairaus stambumo atliekų fizikines ir mechanines savybes bei granuliometrinę sudėtį.
2. Išnagrinėti betono atliekų poveikį portlandcemenčio hidratacijai.
3. Nustatyti frakcionuotų betono atliekų poveikį sukietėjusio betono fizikinėms bei mechaninėms savybėms.
4. Parinkti betono sudėtį, kiek galima didesnį kiekį gamtinio stambiojo užpildo ir smėlio pakeičiant trupintomis betono atliekomis bei naudojant specialią įmaišą, gerinančią gaunamo betono savybes.
5. Nustatyti betono su disperguotomis ir frakcionuotomis betono atliekomis ir polikarboksilatinio superplastiklio įmaiša, fizikines ir mechanines savybes bei ilgaamžiškumą pagal atsparumą šalčiui ir šarminę koroziją.

Tyrimų metodika. Naudotų žaliavų ir sukietėjusio betono pagrindinės savybės buvo nustatomos standartiniais tyrimų metodais ir metodais aprašytais mokslinėje literatūroje. Kontakto zona tarp užpildų iš betono atliekų ir naujai susidarančio cemento akmens buvo ištirta rastriniu elektroniniu mikroskopu, naudojant navigacinę sistemą.

Darbo mokslinis naujumas

1. Pasiūlytas būdas panaudoti frakcionuotas betono atliekas kokybiškų dirbinių gamyboje. Šias atliekas būtina disperguoti ir frakcionuoti ir naudoti kaip stambųjį ir smulkųjį užpildą. Be to, tokias atliekas galima derinti su smulkiu gamtiniu smėliu ir tokiu būdu gauti betoną su analogiškomis savybėmis arba naudoti polikarboksilatinio superplastiklio įmaišą, kuri leidžia pasiekti tankio, įmirkio ir gniuždymo stiprio vertes artimas betono su gamtiniais užpildais savybių vertėms.
2. Ištirtas betono atliekų ir betono atliekų su polikarboksilatinio superplastiklio įmaiša poveikis cemento hidratacijai. Cemento hidratacijos procesus įtakoja betono atliekų kiekis, taip pat šias proceso rodiklių vertes sumažina polikarboksilatinio superplastiklio įmaiša, naudojant ją kartu su užpildais iš trupintų betono atliekų.
3. Ištirtas betono su trupintomis betono atliekomis bei betono su trupintomis betono atliekomis ir įmaiša ilgaamžiškumas pagal atsparumą šalčiui ir atsparumą šarminei korozijai. Į betono mišinį įmaišius plastifikuojančios įmaišos sumažėja masės nuostoliai atsparumo šalčiui nustatymo metu, padidėja apskaičiuotas prognozuojamas eksploatacinis atsparumas šalčiui ir sumažėja betono plėtra šarminėje aplinkoje.
4. Ištirta kontakto zona tarp užpildo, gauto sutrupinus betono atliekas ir naujai susiformavusios cemento akmens matricos. Darbe naudota polikarboksilatinio superplastiklio įmaiša vizualiai monolitina sąlyčio tarp užpildo iš betono atliekų ir skiedininės betono dalies zoną.

Praktinė vertė. Betono atliekų panaudojimas naujų produktų gamyboje leidžia išspręsti atliekų utilizavimo ir gamtos išteklių taupymo klausimus. Šie veiksniai sudaro galimybę betono gaminių rinkai pasiūlyti sunaudoti didelį kiekį atliekų. Ateityje, gaminiai iš tokio betono galėtų pakeisti dalį šiuo metu gaminamų dirbinių ir sumažinti gamtinių išteklių naudojimo tempus.

Ginamieji teiginiai

1. Parinkus tinkamiausias betono mišinių sudėtis ir laikantis reikiamų komponentų kokybinių charakteristikų, betono atliekas galima naudoti betono dirbinių gamyboje kaip stambiuosius ir smulkiuosius užpildus.
2. Polikarboksilatinis superplastiklis pagerina betono, kuriame stambieji ir smulkieji užpildai pakeisti betono atliekomis, savybes bei sąlytį tarp naujai susiformavusios cemento akmens matricos ir užpildo iš betono atliekų.

Disertacijos struktūra. Disertaciją sudaro įvadas, trys skyriai, bendrosios išvados, naudotos literatūros ir disertacijos autorės publikacijų sąrašai.

Darbo apimtis – 121 puslapis, tekste panaudotos 5 numeruotos formulės, 60 paveikslų ir 18 lentelių. Disertacijoje buvo panaudota 120 literatūros šaltinių.

Pirmasis skyrius skirtas mokslinės literatūros apžvalgai ir analizei apie betono atliekas, jų perdirbimą, naudojimą naujų dirbinių gamyboje, o taip pat apie atliekų ir įmaišų poveikį cementbetonio savybėms. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai.

Antrajame skyriuje yra aprašytos darbe naudojamos žaliavos, jų charakteristikos, savybės, bei betono mišinių sudėtys, tyrimo metodai ir įranga.

Trečiajame skyriuje nagrinėjama kaip pakinta betono, pagaminto iš betono atliekų savybės, jei mišiniams buvo naudojami užpildai gauti tik iš frakcinionuotų ir nefrakcionuotų betono atliekų. Išnagrinėtas savybių pokytis jei gamtinis stambusis užpildas iš dalies arba visas pakeičiamas betono atliekomis. Aprašytas tinkamiausios sudėties parinkimo metodas, kai betono mišiniams naudojamos trupintos betono atliekos pakeičiant jomis dalį arba visą smulkųjį užpildą. Taip pat šioje dalyje pateikti tyrimai, kurie atlikti betono mišiniams naudojant polimerines įmaišas ir tikintis pagerinti betono iš betono atliekų savybes, bei padidinti atliekų ir naujai susiformavusios betono skiedininės dalies kontakto stiprumą.

Darbo pabaigoje suformuluotos bendrosios išvados.

Bendrosios išvados

1. Literatūros analizė rodo, kad betono, kurio sudėtyje panaudoti užpildai iš trupintų betono atliekų, tankis ir stipris sumažėja priklausomai nuo įdėtų į mišinį betono atliekų charakteristikų ir kiekio.
2. Atlikus eksperimentinius tyrimus, galima teigti kad:
   - būtina frakcionuoti trupintas betono atliekas, atskiriant nuo jų daleles, kurių skersmuo mažesnis kaip 0,125 mm, nes jos keičia sukietėjusio betono struktūrą, užpildydamos tarpus tarp stambiųjų užpildų, tuo pačiu padidindamos atstumą tarp šių užpildų, formuojančių betono „karkasą“. Betono atliekos sumažina sukietėjusio betono gniuždymo stiprį 25–32 %, tankį – 8–11 % bei padidina įmirkį 31–39 %, lyginant su betonu pagamintu naudojant gamtinius užpildus ir sumažina gniuždymo stiprį 21–26 %, tankį – 3–5 % bei padidina įmirkį 7–9 % lyginant su betonu pagamintu naudojant frakcionuotas (0,125/4 ir 4/16) betono atliekas;
   - betono, kurio sudėtyje panaudoti stambieji (4–16 mm) ir smulkieji (0,125–4 mm) užpildai iš trupintų betono atliekų, gniuždymo

stipris sumažėja 5–8 %, tankis – 8–18 %, prognozuojamas eksploatacinis atsparumas šalčiui – 19–28 %, o įmirkis padidėja beveik du kartus, nes pasikeičia betono struktūra ir naudotų frakcionuotų betono atliekų savybės lyginant jas su gamtiniais užpildais (atliekų stipris 2,5 karto mažesnis, o įmirkis didesnis);
- betono mišiniuose, neblogir
ant betono savybių, galima panaudoti smulkiuosius trupintų betono atliekų užpildus (0,125–4 mm), komponuojant juos kartu su smulkiuoju (stambumo modulis iki 1) gamtiniu smėliu, santykiu 40:60. Tokios sudėties smulkiojo užpildo mišinys užtikrina sutankintą betono struktūrą ir geriausias sukietėjusio betono rodiklių vertes.

3. Polikarboksilatinio superplastiklio įmaiša (0,8 % cemento masės) turi teigiamą poveikį betono, susidedančio iš stambiųjų (4/16 mm) ir smulkiųjų (0,125–4 mm) užpildų iš trupintų betono atliekų, savybėms:
   - 22–24 % mažina vandens poreikį, reikalingą reikiamos konsistencijos betono mišiniui gauti;
   - iki 2 h pailgina egzoterminio efekto maksimalios temperatūros pasiekimo trukmę;
   - 15–17 % mažina vandens įmirkį ir 4–6 % didina betono bandinių tankį;
   - iki 1,5 karto didina sukietėjusio betono gniuždymo stiprį;
   - 48–50 % padidina bandinių prognozuojamą eksploatacinį atsparumą šalčiui, o masės nuostoliai po 56 šaldymo ir šildymo ciklų nesiekia leistinųjų didžiausių ribų.

   Teigiamą polikarboksilatinio superplastiklio įmaišos poveikį galima paaiškinti tuo, kad įmaiša sumažina skystosios fazės paviršiaus įtempimus, užtikrindama geresnį sudedamųjų dalių sukibimą. Be to įmaiša apgaubia užpildą iš trupintų betono atliekų plėvele, kuri neleidžia užpildui absorbuoti didesnius vandens kiekius maišymo metu, tuomet nesusidaro vandens, reikalingo cemento rišimuisi, trūkumo ir sudedamųjų dalių kontakto vietoje neatsiranda plyšelių, gaunamas glaudesnis sąlytis tarp betono sudedamųjų komponentų ir betono struktūros sutankėjimas.
4. Betonas su trupintomis betono atliekomis bei betonas su trupintomis betono atliekomis ir polikarboksilatinio superplastiklio įmaiša yra atsparesni šarminės aplinkos poveikiams dėl galimai mažesnio reaktyvaus SiO_2 kiekio nei betono bandiniai su gamtiniais užpildais.
5. Tyrimai parodė, kad frakcionuotas betono atliekas dideliais kiekiais galima naudoti cementbetonio mišiniuose, nes sukietėjusio betono fizikinės bei mechaninės savybės yra artimos betono, kuriame

naudojami gamtiniai užpildai, savybėms. Tai leistų taupyti neatsinaujinančius gamtos išteklius bei mažintų betono atliekų sąvartynų plotus.

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Padėka

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INFLUENCE OF THE FRACTIONATED CONCRETE WASTE AND PLASTICIZING ADMIXTURE ON THE PROPERTIES OF CEMENT CONCRETE

Summary of Doctoral Dissetation
Technological Sciences, Materials Engineering (08T)

Olga FINOŽENOK

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Daktaro disertacijos santrauka
Technologijos mokslai, medžiagų inžinerija (08T)

2013 12 13. 1,5 sp. l. Tiražas 70 egz.
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