6thSDS2016 SUSTAINABLE DEVELOPMENT SYMPOSIUM

Fundación General UGR-Empresa

CERTIFICATE

We hereby confirm that

Iva Despotović

has given the poster presentation

SELF –COMPACTING CONCRETE WITH INDUSTRIAL WASTE MATERIALS AND RECYCLED AGGREGATE AS A SUSTAINABLE MATERIAL

6th annual european posgraduate symposium
1 - 3 JUNE 2016, GRANADA, SPAIN

on behalf of the Executive Committee,

Juan Luis Rivas Navarro (Coord.)

Universidad de Granada · Diputación de Granada · Ayuntamiento de Granada · etsa · ETS Ingeniería de Caminos, Canales y Puertos · Departamento Urbanística y Ordenación del Territorio · Departamento de Construcciones Arquitectónicas

BOOK OF ABSTRACTS
THE 6th EUROPEAN POSRGRADUATE SUSTAINABLE DEVELPMENT SYMPOSIUM

EDITORS:
Juan Luis Rivas Navarro
Belen Bravo Rodríguez

DESIGN:
Sandra Butautaite
Carolina Curiel

PLACE AND YEAR:
Granada, 1-3 of June of 2016

PUBLISHER:
Godel Impresiones Digitales S.L.

ISBN: 978-84-16478-83-5
Depósito legal: GR 709-2016

SELF – COMPACTING CONCRETE WITH INDUSTRIAL WASTE MATERIALS AND RECYCLED AGGREGATE AS A SUSTAINABLE MATERIAL

Iva Despotović [1]

ABSTRACT

Construction industry uses vast amounts of natural resources, simultaneously producing significant amounts of construction waste, so that it has a great impact on the environment. Annual production of concrete in the world has reached 10 billion tons, classifying concrete in the most widely used building material. Having in mind the fact that 70 % of concrete is aggregate, it is clear what the quantity of natural and crushed aggregates requires. Uncontrolled exploitation of aggregates from rivers seriously disrupts aquatic ecosystems and habitats, while the production of crushed natural aggregates increases harmful gas emissions, primarily of CO2, which are responsible for the greenhouse effect. These gases are formed during blasting rocks and during the transportation of aggregates to the usually distant urban areas. One of the solutions of the mentioned problems is recycling deposited building materials, primarily concrete. Because of the uneven quality, the possibility of various impurities to rest during recycling, larger water absorption and lower bulk density, compared to natural aggregates, recycled aggregates require a series of tests and special technology of concrete making.

Self-compacting concrete, being innovation in the field of concrete technology, contains a certain amount of powdered materials – fillers. There are various possibilities of selecting this component. If we used any of the industrial by-products, such as fly ash or silica fume, we would solve the problem of depositing these materials, and thus made concrete ecological material.

The research subject presented in this paper are properties and technology of self-compacting concrete made with various mineral additives: lime, fly ash, and silica fume, wherein the aggregates used, are both natural and recycled aggregates, obtained by demolition of retaining wall, whose amount is varied in the concrete.

Keywords: Self – Compacting Concrete, recycled aggregate, fly ash, silica fume, lime

---

[1] PhD, Professor, Belgrade University College of Applied Studies in Civil Engineering and Geodesy, Belgrade, Serbia. ivickad@gmail.com

SELF – COMPACTING CONCRETE WITH INDUSTRIAL WASTE MATERIALS AND RECYCLED AGGREGATE AS A SUSTAINABLE MATERIAL

Iva Despotović[1]

ABSTRACT

Construction industry uses vast amounts of natural resources, simultaneously producing significant amounts of construction waste, so that it has a great impact on the environment. Annual production of concrete in the world has reached 10 billion tons, classifying concrete in the most widely used building material. Having in mind the fact that 70 % of concrete is aggregate, it is clear what the quantity of natural and crushed aggregates requires. Uncontrolled exploitation of aggregates from rivers seriously disrupts aquatic ecosystems and habitats, while the production of crushed natural aggregates increases harmful gas emissions, primarily of CO2, which are responsible for the greenhouse effect. These gases are formed during blasting rocks and during the transportation of aggregates to the usually distant urban areas. One of the solutions of the mentioned problems is recycling deposited building materials, primarily concrete. Because of the uneven quality, the possibility of various impurities to rest during recycling, larger water absorption and lower bulk density, compared to natural aggregates, recycled aggregates require a series of tests and special technology of concrete making.

Self-compacting concrete, being innovation in the field of concrete technology, contains a certain amount of powdered materials – fillers. There are various possibilities of selecting this component. If we used any of the industrial by-products, such as fly ash or silica fume, we would solve the problem of depositing these materials, and thus made concrete ecological material.

The research subject presented in this paper are properties and technology of self-compacting concrete made with various mineral additives: lime, fly ash, and silica fume, wherein the aggregates used, are both natural and recycled aggregates, obtained by demolition of retaining wall, whose amount is varied in the concrete.

Keywords: Self – Compacting Concrete, recycled aggregate, fly ash, silica fume, lime

INTRODUCTION

The phrase "Sustainable development" was first used in the report of the World Commission on Environment Our immediate future - also known as Brundtland Report in 1987. This was followed by the World Summit in Rio de Janeiro (1992), the adoption of Agenda 21 (300 pages document) and the establishement of United Nations Commission for Sustainable

[1]PhD, Professor, Belgrade University College of Applied Studies in Civil Engineering and Geodesy, Belgrade, Serbia, ivickad@gmail.com

Development. The generally accepted definition of sustainable development is coming exactly from this report: "Sustainable development is development that meets the needs of present generations without compromising the rights of future generations to meet their own needs". The goal of sustainability is to leave to the future generations as many options as we have had for ourselves. One of the key issues is the awareness of limitation of natural and material resources on our planet. This concept includes not only environmental, but also social and economic interests such as health, safety, concern for the environment, prosperity, plenty of work and a fair distribution of resources. Sustainable construction can be presented as a way of design and construction which is in compliance with human health (physical, psychological and social) and in harmony with the animate and inanimate nature. Model "20 factors" is proposed as way to determine impact on the environment in relation to the achieved progress, which is reduced by these mentioned factors [6].

Design and construction of facilities with satisfying durability within the planned lifetime, as well as the use of renewable natural resources and alternative materials for the construction, are one of the main commitment of modern construction engineering. The main problem is the inevitable demolition of old and worn out facilities and their replacement with new facilities in large urban areas and within traffic infrastructure. Reasons for demolition are change of their purposes, aging - the deterioration of facilities, rearranging of cities parts, expansion of roads and increasing of traffic load, natural disasters (earthquakes, fires, floods) [2]. Construction waste (Figure 1), which occurs as a result of new construction processes and demolition of existing buildings is one of the biggest environmental problems in the European Union, as well as in many developed countries. It is estimated that about 40% of the waste generated due to demolition makes concrete, ceramics 30%, 10% wood, 5% polyester, 5% metal and 10% different residues [5].

Figure 1: Typical construction waste [7]

The main construction waste (materials obtained due to demolition of buildings and infrastructure) represents around 180 million tons per year or 480kg / per person / per year in the EU [10], which is certainly a cause for global concern. The usual method of "management" regarding construction waste in the recent past was his disposal in stock pile depots. That caused a formation of huge stock pile depots of construction waste. Concrete is the world most widely used material for decades, after water; annual production of concrete in the world reached a value of a tone of concrete per inhabitant on the planet [6]. These data made absolutely clear the need for finding new possibilities for obtaining aggregates, where the recycling of deposited materials, primarily old concrete, is the primary option. Problems arise due to lack of space and equipment for sorting of construction waste, experience in the recycling procedures of waste materials, skilled workers and supervisors, knowledge of the secondary materials market, legal regulations in the field of environmental protection, etc. [4].

MATER IALS USED IN OWN EXPERIMENTAL RESEARCH

Self – Compacting Concrete

Self-Compacting Concrete - SCC, according to many authors, as "the most revolutionary discovery in concrete industry of the twentieth century", does not require concrete vibration during placing and compacting. Under the effect of its own weight, concrete fully meets all parts of the formwork, even in case of dense reinforcement. Its benefits are: faster construction process, reduction of the required workers, better final surfaces, easier placing, improved durability, bigger possibility for shaping of elements, noise reduction, absence of vibration, and thereby, healthier work environment. It is estimated that in the usage of self-compacting concrete instead of vibrated decreased labor requirements for about 10%; in the application of precast construction elements, building time is shorter by about 5%, and the demand for workers decreased by about 20%; in the application of sandwich elements (steel - concrete) time saving is 20%, and labor requirements 50%. The main disadvantages of the self-compacting concrete usage are higher prices of material, stringent quality requirements and increasing pressure on the formwork in relation to vibrated concrete [1].

Recycled aggregate

Plants for the production of recycled aggregates are practically the same as plants for the production of natural crushed aggregate. The process of obtaining recycled aggregates is actually crushing of scrap concrete pieces, which causes the creation of granular material of different sizes. Two basic operations required for this are crushing and sieving. Depending on the contamination of the waste material and purpose of the aggregates which is to be produced, further production technology includes separation of metal by a magnetic separator, manually or mechanically removing of stray materials and further washing and air purging or of the final product. Recycled aggregate grain obtained by this recycling method consists of grain (or its part) of natural aggregate and cement mortar of the original concrete, which envelops it partially or completely. The presence of the old cement mortar, which has less density and larger porosity than a grain of natural aggregate, substantially affect a range of physical and mechanical properties of recycled aggregate and concrete based on recycled aggregate as well, i.e. conditions "worse" properties of recycled compared to natural aggregate (Figure 2).

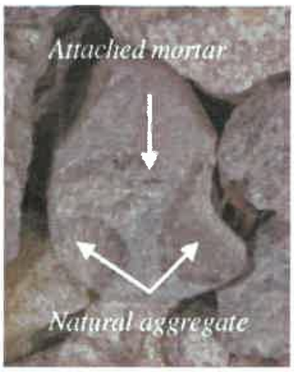


Figure 2: Recycled concrete aggregate [8]

Mineral additives: lime, fly ash and silica fume

Lime is more widely used as a cement additive than a concrete additive. European norm EN197 - 1 provides two classes of Portland cement with lime whose labels are CEM II/L (or L-L instead of A-L) and CEM II/BL (or L-L instead of B-L). The former contains between 6 and 20% of lime and the latter 21 – 35%. Requirements that lime for cement should meet are the following: CaCO3 content should be greater than 75%, clay content, determined by methylene blue test, must not exceed 1.20g/100g, the total content of organic carbon must not exceed 0.20% for LL lime and 0.50% for L lime.

Fly ash - during the combustion of coal in a furnace at temperatures between 1250˚C and 1600˚C, non-combustible particles combine to form spherical glassy droplets of silicate (SiO_2), aluminate (Al_2O_3), iron oxide (Fe_2O_3) and other less important constituents. When fly ash is added to concrete, pozzollanic reaction starts between silicon dioxide (SiO_2) and calcium hydroxide ($CaOH_2$) or lime, which is a by-product of hydration of Portland cement. The resulting products of hydration fill pores reducing the porosity of the matrix.

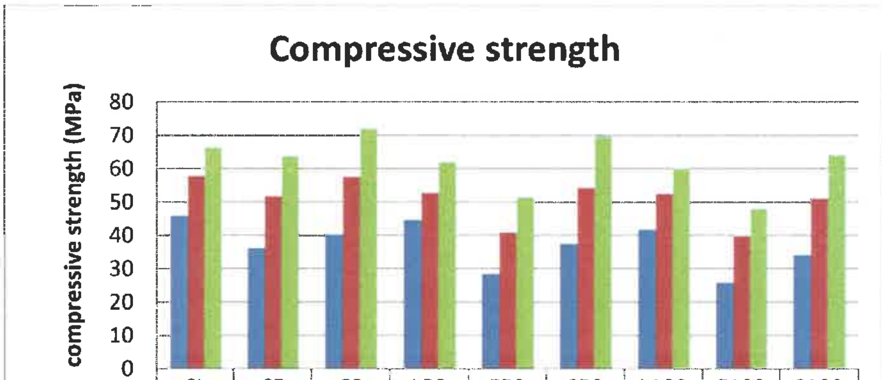
Silica fume is formed during melting quartz at high temperature in an electric arc furnace, wherein silicon or ferrosilicon occurs. High purity quartz is heated to 2000˚C using coal, coke or wood chips as fuel and then electric arc is introduced in order to remove metals. By melting quartz, silicon oxide is released in gaseous state, and it is mixed with oxygen in the upper parts of the furnace, where it oxidizes turning into tiny particles of amorphous silicon dioxide. Particles are carried out from the furnace through the collector and cyclone, where the unburned parts of coal are removed, and then "blown" into the special filter bags. Due to its nature, even a small addition of silica fume significantly changes physical and chemical properties of concrete.

EXPERIMENTAL RESEARCH

For the purpose of the experimental part of the work, it was made nine different three-sized fracture concrete mixtures, with the mineral additions such as ground limestone, fly ash and silica fume; control concrete (C) are made with all of the extras and river aggregate; by mixtures of L50, F50 and S50 is the fraction 8/16 mm replaced by recycled aggregate, and in a mixture of L100, F100 and S100 are both coarse fraction (4/8 and 8/16 mm) replaced with recycled (Table 1).

Table 1: Concrete mixes

	Cement (kg/m3)	Lime (kg/m3)	Fly ash (kg/m3)	Silica fume (kg/m3)	0/4mm (kg/m3)	4/8mm (kg/m3)	8/16mm (kg/m3)	Water (kg/m3)	VSC5380 (kg/m3)
CL	400	120	0	0	770.86	306.28	532	170.8	4.94
CF	400	0	120	0	770.86	306.28	532	192.66	4.94
CS	400	0	0	52	770.86	306.28	532	185.71	4.94
L50	400	120	0	0	809.14	306.28	505.43	182.86	5.08
F50	400	0	120	0	809.14	306.28	505.43	214.28	5.08
S50	400	0	0	52	809.14	306.28	505.43	197.14	5.08
L100	400	120	0	0	809.14	306.28	505.43	189.5	5.08
F100	400	0	120	0	809.14	306.28	505.43	221	5.08
S100	400	0	0	52	809.14	306.28	505.43	208.6	5.08



	CL	CF	CS	L50	F50	S50	L100	F100	S100
2 days	46	36,34	40,4	44,82	28,68	37,75	41,86	26,2	34,38
7 days	58,24	52,18	58,05	53,12	41,24	54,67	52,86	40,18	51,59
28 days	66,68	64	72,31	62,17	51,7	69,7	60,3	48,2	64,5

Figure 3: Compressive strength

A lot of concrete tests were done, and the most important concrete property – the compressive strength , is presented in this paper. The highest value of compressive strength (Figure 3) after two days had control concrete with limestone and the lowest mixture with fly ash and recycled both coarse fractions - F100. The difference was 19.8 MPa (43%). After 7 days control concrete with limestone and silica fume had almost the same compressive strength (58 MPa) while the mixture of P100 reached 40.18 MPa (difference of 17.82 MPa, i.e. 30.7%). After 28 days, the maximum value of compressive strength is attained with silica fume control concrete 72.31 MPa, while the lowest mixture of F100, 47.2 MPa (difference of 25.11 MPa, i.e. 34.7%). Observing mixtures with limestone, it can be concluded that the differences in achieved compressive strength by the use of natural and recycled aggregates are relatively small – 4.51 MPa (6.8%) and 6.38 MPa (9.6%) - comparison with standards mixtures with replaced one or both coarse fractions. By mixtures with fly ashes difference is 12.3 MPa (19.2%) and 16.8 MPa (26.2%). The bigger difference in compressive strength within the mixtures with the fly ashes can be explained by the uneven quality of recycled aggregates, which represents a major problem within its application. In the group of mixtures with silica fume difference between the control concrete and the other two mixtures goes to 2.61 MPa (3.6%) and 7.81 MPa (10.8%). Fastest increase of strength had mixtures with silica fume.

CONCLUSIONS

Compressive strength differences between concrete with silica fume and limestone does not exceed 10% at the same cement quantity, whereby the concrete with limestone had a better performances in the fresh state. This fact should be borne in mind, especially if we include the economic factor in the equation.

Compressive strength differences between concrete with fly ash and with silica fume are in range from 13% (for standards) to 37% in concrete with recycled coarse aggregate, while concrete mixtures with fly ash have greater ecological value, because it solves the problem of depositing huge quantities of fly ash.

The main problem regarding the application of recycled aggregates is increased porosity, which is caused by old cement paste at aggregate grains. Cement paste is also responsible for unequal quality of the aggregates and it leads to a reduction in compressive strength of concrete. There are methods of aggregates "purifying", which increase the cost of concrete, but the environmental benefits are significant.

Applying of all three mineral additions, opens possibility for obtaining self-compacting concretes of high performances. The main addition is silica fume, but having in mind economic and environmental components of fly ash, as well as the slight difference in obtained results, it should certainly be taken into account. Due to the use of recycled aggregates, these concrete types could be classified as ecological.

REFERENCES

1. Corinaldesi V., Moriconi G. 2009. "Influence of mineral additions on the performance of 100% recycled aggregate concrete". *Construction and Building Materials* 23: 2869–76.
2. Despotović, I. 2015. "Svojstva samougrađujućeg betona spravljenog sa recikliranim agregatom i različiitim mineralnim dodacima". *Građevinski materijali i konstrukcije* 58, no.4: 3-20.
3. Janssen G., Hendriks C.F. 2002. "Sustainable use of recycled materials in building construction". *Advances in Building Technology*, Volume 2: 1399 – 1407.
4. Malešev M., Radonjanin V., Marinković S. 2010. "Recycled Concrete as Aggregate for Structural Concrete Production", *Sustainability 2010*, no.2: 1204- 25, doi:10.3390/su2051204.
5. Oikonomou N. 2005. "Recycled concrete aggregates". *Cement & Concrete Composites* 27: 315–18.
6. Radonjanin V., Malešev M., Marinković S., Ab Malty A. 2013. "Green recycled aggregate concrete". *Construction and Building Materials* 47: 1503–11.
7. www.hawersrecycling.co.uk
8. www.masterbuilder.co.in

ACKNOWLEDGEMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications", supported by the Ministry for Science and Technology, Republic of Serbia. This support is gratefully acknowledged.