LIGHT-WEIGHT CLAYDITE AND SAWDUST CONCRETE BASED ON SUPERSULPHATED CEMENT

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Abstract

The paper gives coverage on the peculiarities of the properties of two types of lightweight concrete: claydite (light-weight expanded clay aggregate - LECA) concrete and sawdust (wood shavings) containing concrete. The first one is based on LECA produced in Western Ukraine and Moldova, for the second one sawdust of the common local coniferous trees was applied. There was used supersulphated cement composed of blast furnace granulated slag, phosphor-gypsum and Portland cement in the research. The calcium chloride was used to reduce retardation and superplasticizer for reduction of water demand in order to increase the compressive strength. High specific surface of supersulphated cement facilitates intensive hydration of CaO from slag glass and binding it into new formations. That increases the strength of light-weight concrete. With claydite, the process occurs with binding of free lime and gypsum with aluminates from slag and aggregate. The results obtained with the claydite concrete were varied within the range of average density from 960 to 1490 kg/m^3 and compressive strength from 7 to 21.5 MPa. Such concrete can be applied for structural and thermal-insulating elements (walling blocks and panels). With sawdust concrete, the average densities were varied from 410 to 720 kg/m^3 and compressive strength from 0.34 to 4.7 MPa, which can be used for structural and non-structural elements. As supersulphated cement had low operating pH due to the limited content of alkali, it led to a positive influence on sawdust aggregate and didn't result to a significant extraction of tanning agents.

Keywords:

Wood shavings, LECA (light-weight expanded clay aggregate), claydite, supersulphated cement (SSC), light-weight concrete

1 INTRODUCTION

Supersulphated cement (SSC) is an effective low-energy environmentally friendly non-clinker cement [Juenger 2011, Ding 2014]. Its basic components are chemical and industrial by-products phosphogypsum (PG) and blast furnace slag with addition of sulphate and alkaline activator in small relative quantity. Normally the proportion of the components is as follows: 70-90% of granulated blast furnace slag (GBFS), 10-20% of calcium sulphate component and up to 5% of alkaline activator [Stark 2000, Hewlett 2004, Juenger 2011].

According to published results [Midgley 1971, Stark 2000, Hewlett 2004, Matschei, 2005], hydrated SSC consists dominantly of ettringite crystals and needle-shaped or plate-like low-basic calcium hydrosilicates, hydrotalcite ($Mg_6Al_2(CO_3)(OH)_{16}\cdot4(H_2O)$), minor AFm phases along with presence of anhydrous slag and gypsum.

The previous research was devoted to the determination influence of the low-alumina blast furnace slag and phosphogypsum dehydrate on the SSC properties [Dvorkin 2012].

For production of cement based light-weight concrete different aggregates are applied [Sonebi et al., 2013].

Series of researches proved the influence of several main factors on light-weight concrete strength: w/c ratio, aggregate strength, porosity of the interfacial zone and within the hardened cement paste [Lo 2007].

The light-weight expanded clay aggregate (LECA) is one of the most common light-weight aggregate. There is shown a possibility to obtain structural light-weight concrete with density below 2000 kg/m^3 and increased compressive strength up to 14% even at partial replacement of coarse aggregate with recycled LECA [Bogas et al. 2015, Boarder et al. 2016].

The durability of light-weight concrete based on expanded clay is proved to increase when mineral admixtures like fly ash and mixes of fly ash and metakaolin are added [Hubertova 2013].

Sawdust concrete is known as eco-friendly low cost aggregate for light-weight concrete, normally applied for ordinary cement based composites [Paramasivam 1980, Kumar 2014]. There are known researches on application the sawdust as fine aggregate for concrete [Ganiron Jr, 2014]. There is suggested to use wood wastes (shavings) to light-weight concrete for improving thermal conductivity of concrete [Bederina 2007].

Wood wastes are local wastes formed mostly in the countries or regions with high percentage of forest lands. Even in the comparatively limited forestry regions where recycling industry is not well-developed such wastes as sawdust become underutilized by-products. [Bdeir 2012]. Regardless the fact that sawdust by itself is flammable – according to some local standards sawdust concrete based on mineral binders is a material, which does not support fire. According to the other known standards such concrete considered as material difficult to ignite (B1 rating).

It was supposed that supersulphated cement can be used as binder for light-weight concrete based on porous aggregates, like expanded-clay aggregate (claydite) concrete and sawdust concrete. The preliminary researches proved that there is unreasonable to produce cellular concrete (both foam and gas concrete) based on supersulphated cement. Due to the low content of clinker and lime, alkalinity of cement is insufficient in cement paste. It complicates gas forming at reaction of hardening products with the most common gas-forming agent – aluminum powder. For the same reason, there is observed substantial reduction of hardening rate of foam concrete at application of modern foaming agents. It results in gaining lower strength values, than required.

2 AIM AND SCOPE OF RESEARCH

Regarding the information given above, the investigation was aimed to develop the compositions of light-weight concrete based on local porous aggregates – both mineral and organic natural by origin.

The main aim of this research is to investigate the structural and mechanical properties of two types of light weight concrete: based on supersulphated cement (SSC) and LECA, and another one - SSC and sawdust based and to define the area of possible application.

The scope of the research is the determination of density and compressive strength of SSC based light-weight concrete specimens to compare with ordinary PC based specimens.

3 MATERIALS AND METHODS

3.1 Materials

The following materials were used in this investigation.

For manufacturing LECA concrete there were applied two types claydite with different density (see Tab. 1).

The first one is expanded clay gravel with average density 350 kg/m^3 by Macon (ChiЇşinău, Moldova).

As a fine aggregate, there was applied quartz sand (Tab. 2).

Shavings of the coniferous trees, wide-spread in region, were applied for sawdust concrete production. The bulk density is 150 kg/m^3, the length is up to 50 mm.

Supersulphated cement with activity (compressive strength) 35 MPa was applied (Tab. 3)

Tab. 1: Properties of light-weight expanded clay aggregate.

#	Manufacturer	Bulk density, kg/m^3	Particle size, mm
1	Macon (ChiЇşinău, Moldova)	350	5-10
2	Yavoriv construction materials plant (L'viv region, Ukraine)	500	5-20

Tab. 2: Properties of quartz sand.

Manufacturer	Fineness modulus	Dust particles, %
Netishyn sandpit (Khmelnytskyi Oblast, Ukraine)	1.9-2.0	Up to 1.7

Tab. 3: Properties of supersulphated cement.

SSC composition, %			Specific surface
GBFS	PG	PC	m^2/kg
85	10	5	615

Portland cement (PC) *CEM II*/B-S 32,*5* R was used for sawdust concrete and blast-furnace slag cement (BFSC) CEM III/A 32.5R for claydite concrete according to EN 197-1:2011 (ДСТУ Б EN 197-1:2015).

For reduction of water consumption of light-weight concrete mixtures and increasing the concrete strength polycarboxylate based superplasticizer (SP) Melflux 2651F was used. Due to the presence of long side chains and prevalence of steric effect over electrostatic, it has significant water reducing effect in low cement binders like gypsum and SSC, comparing to naphthalene formaldehyde superplasticizers [Lushnikova 2015].

For regulation of hardening rate of sawdust concrete commercial calcium chloride was used.

3.2 Test methods

Slump of fresh light-weight concrete was 3 to 4 cm (S1) according ASTM C 143. Cube specimens concrete of 15 cm were casted and tested at 28 days. Average density was tested according ASTM C 567, compressive strength ASTM C 39.

For each composition there were tested 3 specimens and average values of density and compressive strength were determined.

4 RESULTS AND DISCUSSION

Compositions of light-weight concrete C8/10 and C12/15 compressive strength classes have been calculated according to the methods, by Orentlicher (1983).

4.1 Expanded clay aggregate concrete

The results of concrete proportioning are given in Tab.4. There have been tested two groups of specimens #1-4 – with coarse gravel with lower bulk density and #5-8 with higher bulk density. The specimens # 1 and 5 were control for the first and second groups correspondingly.

The results of testing density and compressive strength are shown in Tab. 5.

Tab. 4. Compositions of light-weight expanded clay aggregate concrete, kg/m^3.

#	SSC	BFSC	Water	W/C	Sand	Expanded clay gravel 350	Expanded clay gravel 500	SP
1	-	400	200	0.50	200	400	-	-
2	300	-	150	0.50	200	400	-	
3	300	-	120	0.40	200	400	-	1.6
4	400	-	190	0.48	200	400	-	
5	-	400	210	0.53	500	-	500	
6	300	-	185	0.62	500	-	500	
7	400	-	200	0.50	500	-	500	
8	400	-	140	0.35	500	*	500	1.6

Tab. 5. Structural and mechanical properties of light-weight expanded clay aggregate concrete

# of compo-sition	1	2	3	4	5	6	7	8
Density, kg/m^3	1065	965	962	1075	1505	1355	1490	1480
Compres-sive strength, MPa	9.7	7.1	11.6	10.9	15.3	10.8	17.0	21.5

As it can be seen from Tab. 5, the density of the concrete as well as compressive strength depends on the bulk density of the LECA. Gravel with bulk density 350 kg/m^3, as finer aggregate, requires significantly lower sand consumption for preparing uniform concrete mixture. Application of the superplasticizer permit to reduce water requirement at 20-30%. The effect is more valuable when LECA with higher bulk density is applied.

The relative values of the density and compressive strength of the concrete comparing to control blast-furnace slag cement specimens are shown on Fig. 1 and 2. At the same binder content the substitution of BFSC for SSC does not lead to decreasing the structural and mechanical properties (Fig. 1, #4), (Fig. 2, #7).

The adding of SP at reduction of water-cement ratio leads to increasing compressive strength at 20% for LECA 350 (Fig. 1, #3) and 41% at application LECA 500 (Fig. 2, #8). When LECA 350 is used, the density of concrete can be reduced below 1000 kg/m^3.

According to the values of density such LECA concrete can be applied for structural and non-structural (thermal insulating) purposes, like production of walling blocks and panels. The properties of SSC based LECA concrete are similar values to that based on BFSC concrete.

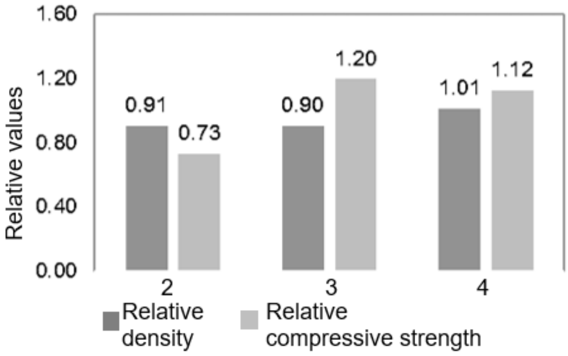

Fig. 1. Relative density and strength of SSC based LECA concrete comparing to BFSC based concrete (LECA 350)

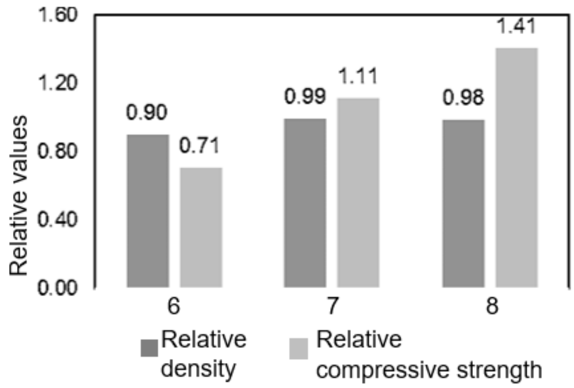

Fig. 2. Relative density and strength of SSC based LECA concrete comparing to BFSC based concrete (LECA 500)

4.2 Sawdust (wood shavings) concrete

At proportioning sawdust concrete, there were applied recommendations [Dvorkin and Dvorkin, 2006] (Tab. 6). Concrete compaction of fresh sawdust concrete was vibration with cantledge 2.5kPa.

Sawdust concrete compositions are given in Tab. 7. According to the results received, concrete based on low-aluminous supersulphated cement for non-structural concrete can be manufactured.

Low alkalinity of SSC has positive impact on the interaction of the binder with wooden aggregate and do not lead to the substantial evolution of extractive substances.

Tab. 6. Compositions of sawdust aggregate concrete, kg/m³.

#	SSC	PC	Water	W/C	Saw-dust	$CaCl_2$
1	-	450	310	0.69	250	-
2	-	480	330	0.69	250	-
3	225	-	300	1.33	260	-
4	225	-	310	1.38	250	2
5	450	-	310	0.69	250	-
6	450	-	330	0.73	250	2
7	490	-	340	0.69	250	2

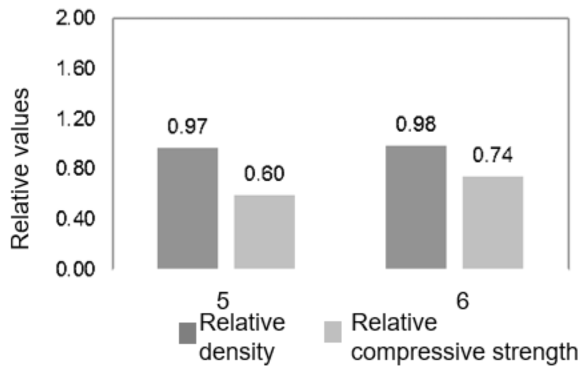

Fig. 3. Relative density and strength of SSC based sawdust concrete comparing to PC based concrete (compositions #5 and6)

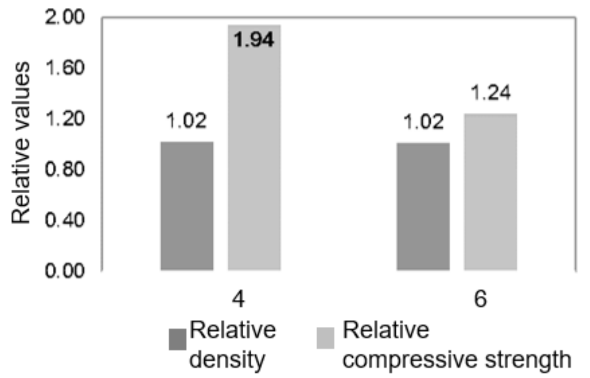

Fig. 4. Relative density and strength of SSC based sawdust concrete with $CaCl_2$ comparing to specimens without $CaCl_2$ (compositions #4 and6)

Tab. 7. Structural and mechanical properties sawdust concrete

# of composition	1	2	3	4	5	6	7
Density, kg/m³	710	710	411	420	688	699	798
Compressive strength, MPa	3.11	4.68	0.34	0.66	1.86	2.31	4.34

Water solution of $CaCl_2$ was applied for increasing the hardening rate (2.0% of SSC weight) As it can be seen from Tab. 7 and Fig. 3 and 4, the specimens of SSC sawdust concrete without $CaCl_2$ admixture do not meet the requirements to the strength, their hardening rate is extremely slow and demolding is possible not earlier than 3 days of hardening. Whereas at adding $CaCl_2$ at 1 day of hardening there is possible to demold the specimens.

5 CONCLUSIONS

The paper summarizes the results of studying the basic properties of light-weight concrete based on supersulphated cement and local mineral and organic aggregates: expanded clay (claydite) and sawdust. There is proved that at application of relevant chemical admixtures - superplasticizers for LECA concrete) and $CaCl_2$ for sawdust concrete such concrete can be applied for structural and thermal insulating units.

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