# Research of self-compacting concrete with light aggregates

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## Summary

Lightweight artificial aggregate Liapor is customary used for the manufacture of porous lightweight concrete, for instance for the manufacture of shaped bricklaying blocks. In smaller extent these aggregates are used for monolithic structures into which the concrete is mostly laid by means of concrete pumps. The objective of this experimental work is to propose a suitable composition of lightweight dense concrete using the Liapor aggregate, size fraction 4-8 and 8-16 mm for the technology of concrete casted by concrete pumps.

**Keywords**: lightweight aggregate, self compacting concrete, pumping of concrete, fresh and hard set concrete, rheological properties

## 1. Introduction

### 1.1. Lightweight concrete (LC)

Lightweight concrete is defined as concrete which has after draying the volume mass higher than 800 kg/m$^3$ and smaller than 2000 kg/m$^3$. This concrete is manufactured completely or partially from lightweight aggregates, further components are cement, water, admixtures and additives. .

The main advantage of lightweight concrete is the low volume mass while maintaining relatively high mechanical strength. Thanks to low volume mass lightweight concrete has outstanding heat and sound insulation properties, and higher fire-resistance.

From the point of view of utilization the lightweight concrete can be divided into structural (dense) concrete the main function of which is the carrying capacity and the main demand is the strength under utilization of low volume mass, structural insulation lightweight concrete where parallely the load-bearing and heat insulating capacity is utilized and the heat-insulating (porous) concrete applied especially for utilization of its heat-insulating properties.

Lightweight concrete is produced in stable plants and used for the manufacture of building elements, or it is delivered to building sites as transport concrete which represents the greatest volume of concrete placed in building industry.

### 1.2. Self compacting concrete (SCC)

Self compacting concrete is defined as a compact, highly liquid concrete mixture, which is placed into structure with minimum compacting or without compacting at all. It is a more-components composite silicate system with main components such as Portland cement , fine and coarse aggregates with adequate grain size composition and secondary modifying components (such as super-plasticizers, fine fillers with high specific surface of particles, substances modifying the viscosity and water separation, antifoaming agents). The flowing capacity of SCC without the effect of external dynamic power with high resistance against separation and segregation of fresh concrete coarse particles makes possible to fill up the boarding even in the case of close meshed reinforcement without applying vibration for compacting. Thanks to special composition a rapid increase of strength values takes place under high quality of surface.. The high mobility has to be secured for the period of at least 90 minutes.

For the description of fresh self compacting concrete in present practice the following tests are used: the test with Abrams cone, L-box test, J-Ring test, Orimet test, J-Ring and Orimet test, V-Funnel test, U-shape test and Box-shape test, Filling Vessel test, GTM-test

### 1.3. Self compacting lightweight concrete (SCLC)

Self compacting lightweight concrete is a new building material which combines the well known advantages of lightweight dense concrete and of self compacting concrete. Self compacting lightweight concrete can be owing to its properties utilized especially for the reconstruction of old buildings for which the elevation of weight would be not adequate and also in the manufacture of prefabricated elements for structures with complicated shape where strength values up class C30/37 are sufficient. This in the case of element weight reduction by 25 till 30 % can significantly reduce the load of structure and better utilize the mechanical properties.

## 2. Lightweight aggregates LIAPOR®

Liapor (keramsite) is a very light granulated material manufactured by expansion of natural cypress clay. It is essentially a ceramic material. It is significant by its granulated character with nearly spherical grains and a regular internal porous structure with closed sintered surface.

The aggregate generally forms 75 till 80% of concrete volume. The main function is the formation of solid concrete skeleton therefore it contains grains of different size in adequate relation. This can be achieved by a suitable combination of different aggregate fractions and by observing the definite grain-size curve. When using lightweight aggregates it is adequate to use aggregate with approximately identical volume mass. This considerably reduces the risk of heavier grains segregation in fresh concrete.

In the production of aggregates the pellets from pre-crushed and plasticized raw material pass the rotary kiln and they increase in volume at the temperature 1100 – 1200°C. The passage time of the material in the kiln necessary for the expansion itself should be 10 till 15 minutes. The total time of passage is 45 till 60 minutes. The optimum moisture of granules when entering the kiln is 8 – 10%. During burning the surface of grains sinters and the hollow pores in the grains increase in volume. Afterwards the expanded granulate passes the cooler. After the burning process a long, slow cooling period follows, which removes the internal stress and in this way increases the strength of Liapor.

The cooled granulate is transported to a classifier and sized in individual fractions.

The characteristic properties of Liapor lightweight inorganic aggregate you will find in following table no.1.

*Table 1. Characteristic properties of Liapor lightweight aggregate*

| Bulk mass | 250 – 900 kg/m3 |
|---|---|
| Volume mass | 500 – 1900 kg/m3 |
| Porosity of loosely piled Liapor | 40 – 50 % |
| Porosity of crushed Liapor | 55 – 65 % |
| Coefficient of heat conduction $\lambda$: | > 0,09 W/m.K |
| Compression strength in a cylinder | 0,7 – 15 MPa |
| Durability | Mechanically resistant, chemically stable, resistant against acids and lye, stable in water and it neither dissolves nor liberates harmful leaches or gases |
| Fire-resistance | fire-resistant and stable volume up to 1150°C |
| Moisture | |
| -when stored in closed silos | < 1 % of mass |
| -when stored in open stock piles | 1 – 25% of mass |

| | | |
|---|---|---|
| Absorptivity | not hygroscopic, does not accept humidity from air | |
| | Mass | Volume |
| - after 30 minutes | 2 – 7 % | 1 – 4 % |
| - after 24 hours | 7 – 19 % | 6 – 8 % |
| - after 48 hours | 20 – 25 % | 11 – 13 % |
| - after 120 hours | 22 – 30 % | 13 – 16 % |
| -after 180 days | 30 – 45 % | 18 – 24 % |
| Frost resistance | the porous, non-capillary structure of the grain enables frozen water dilatation, therefore it resists to repeated freezing | |
| Volume stability | after shaking stable volume | |
| Unexceptionable sanitary nature | it liberates neither gaseous emissions nor leaches harmful for men | |
| Sulphates and chlorides content | the sulphur content is 0,2-0,5% mass<br>the chlorides content is 0,005-0,01% mass | |
| Content of organic and heterogeneous particles | the loss of ignition (1000°C) is zero | |

The chemical composition of Liapore you will find in table 2.

*Table 2. The chemical composition of Liapor*

| | % mass. |
|---|---|
| $SiO_2$ | 52 |
| $Al_2O_3$ | 23 |
| $Fe_2O_3$ | 10 |
| CaO | 5 |
| $K_2O$ | 2 |
| MgO | 2 |
| $TiO_2$ | 2 |
| $P_2O_5$ | 2 |
| other | 2 |

Note: Tolerance for individual components is ± 5%

## 3. Experimental part

The aim of experimental work was to project a SCC composition with utilization of lightweight aggregates Liapor with maximum fraction 8 mm and different volume masses. The examples of tested formulae are in the following table no. 3.

*Table 3. Examples of projected formulae for 1 m³*

| | *Formulae1* | | *Formulae 2* |
|---|---|---|---|
| Cement CEM I 42,5 R Mokrá | 360 | Cement CEM I 42,5 R Mokrá | 400 |
| Liapor 4–8/450 | 201 | | |
| Liapor 0-4(67)/550 | 293 | Liapor 0-4(67)/550 | 755 |
| Liapor 0-1D/650 | 227 | Crushed aggregate 4-8mm | 343 |
| water/cement ratio | 0,45 | water/cement ratio | 0,45 |
| Water | 175 | Water | 183,6 |
| Additional water | 180 | Additional water | 86 |
| Power plant fly ash | 72 | Microsilica | 40 |

| | | | |
|---|---|---|---|
| Chvaletice | | | |
| Stabilizer SPP | 1,44 | Stabilizer SPP | 1,6 |
| Plasticizing additive Glenium 27 | 4,32 l | Plasticizing additive Glenium 27 | 4,8 l |

In the suggestion of formulae always three fractions of lightweight aggregates were used, alternatively one fraction was substituted by natural quarried aggregate. The water/cement ratio was determined as water : fine particles < 0,125 mm incl. cement and admixtures. For reasons using lightweight aggregates with high absorptivity additional water had to be added into the batch always in the quantity of 25% in relation to the quantity of lightweight aggregates. Brown coal power plant fly ash was used as admixture normally, always in the quantity of 40% from cement mass.

During mixing after dosing all fractions of aggregate into the mixer, the dose of additional water was added and it was mixed for at least 30 seconds. Afterwards cement, powder admixtures and additives were added followed by effective water. The liquid additives have to be added after mixing the aggregates with effective water, or they can be mixed with the rest of effective water in order not to be absorbed without control by Liapor. The minimum period of mixing is 60 s in order to achieve the demanded homogenization and the effect of super-plasticizer.

### 3.1. Testing of fresh concrete properties

To evaluate the rheological properties of fresh concrete mixtures three basic test methods were applied – the test with Abrams cone, Orimet in combination with J-Ring test and L-Box test. In all samples of fresh concrete the volume mass was determined after placing the concrete into moulds.

*Fig.1. Photograph of consistency by spreading after mixing and after pumping – formula 1.*

### 3.2. Testing of hardened concrete properties

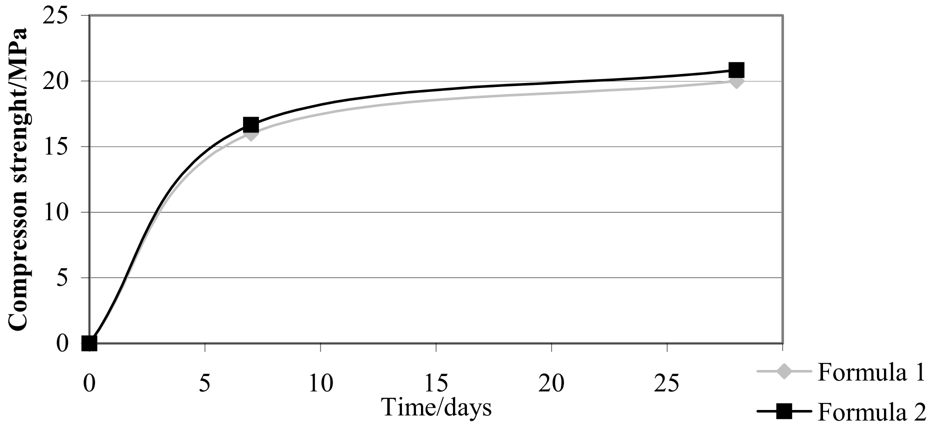
In the case of hardened concrete following properties were tested:

- determination of volume mass
- determination of compression strength after 7 and 28 days of standard curing
- surface resistance against frost, water and chemical defrosting agents effect
- frost resistance of concrete
- absorptivity of concrete

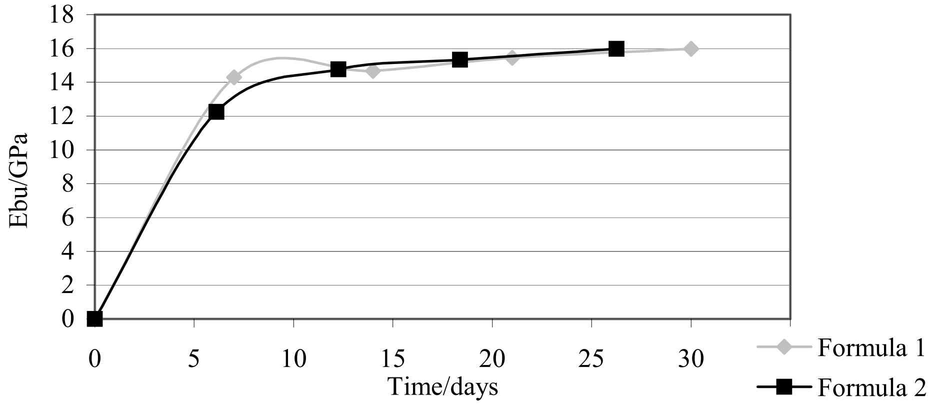
The measured values of realized experimental work are in the next table no. 4.

*Table 4. Measured values*

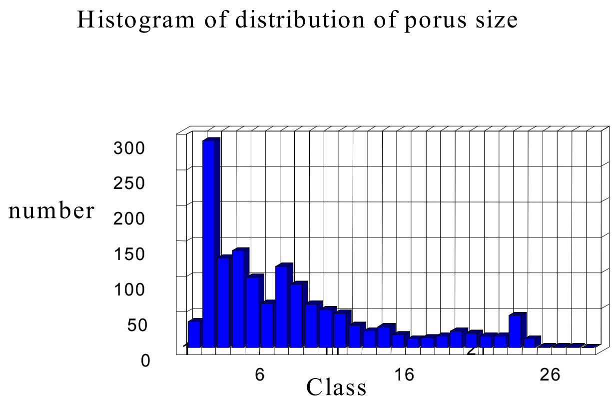
| | *Formula 1* | *Formula 2* |
|---|---|---|
| Bulk mass of fresh concrete | 1400 kg/m$^3$ | 1670 kg/m$^3$ |
| Bulk mass of hardened concrete | 1280 kg/m$^3$ | 1640 kg/m$^3$ |
| Compression strength after 7 days | 16 MPa | 20 MPa |
| Compression strength after 28 days | 20 MPa | 25 MPa |




*Graph 1. Compression strength of samples following mentioned formulae*




*Graph 2. Dynamical E-modulus of samples following mentioned formulae*




*Graph 3. Evaluation of air-pores characteristic in samples following formula no.1*

## 4. Conclusion

Following the realized experiment we can say that the lightweight aggregate Liapor is appropriate for manufacture of self-compacting-concrete namely owing to the spherical shape of grains which make easier the mobility of fresh concrete.

The absoptivity of aggregates influencing the rheology of fresh concrete and the properties of hardened concrete was solved by application of additional water. By careful mixing of aggregate grains with water a sufficient absorption of grains was secured and in this way the removal of batch water which is necessary for good workability and hydration of concrete didn't take place.

The lightweight self-compacting-concrete has a good frost-resistance but it is not water- resistant and not resistant against defrosting agents. The projected concrete mixtures showed good heat-insulating properties. A disadvantage of Liapor aggregate is the low compression strength of grains which is approximately one fifth till one tenth of cement mortar strength. This significantly decreases even the strength of lightweight concrete.

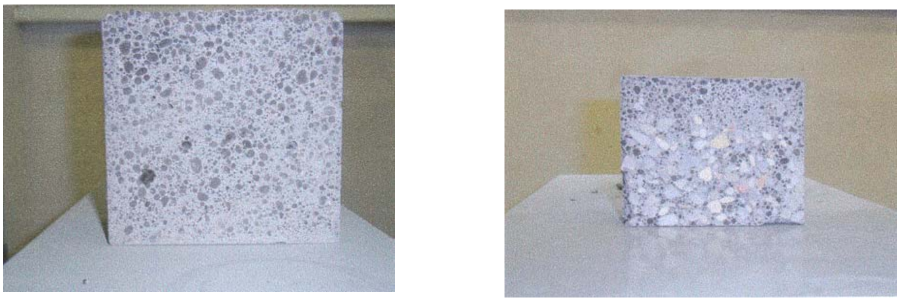


*Fig.2. Cut through test pieces formulae 1, 2*

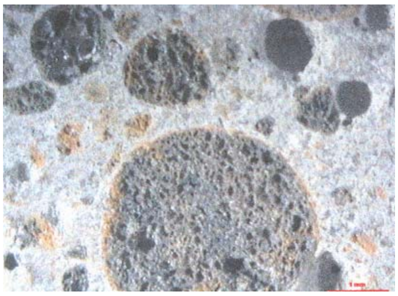


*Fig.3. Cut through test piece following formula 1, magnification 90 x.*

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