EXPANDED CLAY THERMO INSULATING CONCRETE

Michala Hubertova
Lias Vintirov, lehky stavebni material k.s., 35744 Vintirov, Czech Republic,hubertova@liapor.cz

Rudolf Hela
Brno University of Technology, Faculty of Civil Engineering, Veveri 331/95, 60200 Brno, Czech Republic, hela.r@fce.vutbr.cz

Roman Stavinoha
Brno University of Technology, Faculty of Civil Engineering, Veveri 331/95, 60200 Brno, Czech Republic, stavinoha.r@fce.vutbr.cz

Summary

The paper describes methods of designing expanded clay thermo insulating concrete with light-weight expanded clay aggregate Liapor. It also observes upon problems of maintaining rheological properties for longer periods (90 minutes min.) with light-weight aggregate, which has very high water-absorbing capacity. This type of concrete is interesting not only for its capacity to lighten building structures but also for its good compressive strength or excellent heat insulating properties of ultra light-weight concrete. The paper also states practical experience gained at different constructions.

Keywords: expanded clay, insulating concrete, Liapor aggregate

1 Introduction

Application of lightweight self compacting concrete (LWSCC) with expanded clay aggregate (trade name Liapor) are used more frequently in Europe in recent time. Using porous aggregate for high strength concretes might be surprising considering importance of strength of aggregate for strength of high-strength concrete. Lightweight aggregate (LWA) is porous and not very strong. Nevertheless, drop of volume weight of concrete with strength of 40 - 50 N/mm^2 below 1800 kg/m^3 can represent certain cost saving due to reduction of total construction weight.

Thanks to favorable physical properties, low volume weight and relatively high strength combined with good workability, low noise emission and reduction of consumed work in the course of placing, there is a wide range of application for LWSCC, in particular in the field of prefabricated elements and reconstruction of old buildings, where extra load would be undesirable.

LWSCC was for the first time in the Czech Republic applied in 2005. This enabled a comparison of properties of fresh and hardened concrete mixed in laboratory and the same formula mixed in-situ in the mixing plant. The comparison unambiguously proved that it is possible to produce and place LWSCC in practice, in spite of certain differences and high sensitivity of proportioning, batching and mixing. Applications of LWSCC with volume weight 1500 to 1800 kg/m^3 and compressive strength up to 50 N/mm^2 are widely known now. Some examples from the past two years:

- reconstruction of an old building from 15th century – lightening of three-floor building by using LWSC for floor slabs – concrete placed by pumping without negative vibrations
- precast elements – production of bleachers benches for sports stadium Eden Prague and multi-functional hall in Carlsbad (direct-finish concrete)
- precast elements – production of balcony banister for renovation of prefabricated buildings (minimal load necessary)
- three-dimensional prefabricated parts – manufacture of car-shelters and bathroom cells for flats and hotels

Architects have supported the use of light-weight concrete for face or direct finish purposes in recent time. Several buildings were constructed form direct finish thermo-insulating concrete in Switzerland and Germany. The advantage of direct finish concrete is its high architectonic value. Monolithic single-ply bearing constructions cast from concrete have especially high durability, since there are no plaster coats and covering (which brings more cost saving of work and material). The conception of light-weight concrete also saves costs of thermo-insulation (no need for sandwich-type structures).

One of the most interesting and extraordinary applications was the use of thermo-insulating concrete with dry volume weight below 1000 kg/m^3 for construction of a family houses. A Swiss architect Patrick Gartmann designed and built a family house near the town of Chur. The main idea was to cast a house from concrete, with free formation, massive and homogeneous. This very successful project was the initial idea of development of mix design of concrete of similar or higher performance from raw materials available on the Czech market. The main requirement was to design a structural material for perimeter structures in the form of direct finish thermo-insulating light-weight concrete. Thickness of load bearing perimeter walls should not exceed 450 mm. Concrete for all structures was intended to be direct finish. Delivery of concrete to the site was required to be in the form of ready mix.

2 Mix design, fresh concrete, application

Material used for the house of architect Gartmann in Switzerland was lightweight concrete with volume weight 1100kg/m^3 and compressive strength 11 N/mm^2, coefficient of heat conductivity λ=0,3 W/mK. Because standards in the Czech Republic are more rigorous, we had to design concrete with heat conductivity coefficient λ smaller than 0.25 W/mK. We had to solve a problem of designing very lightweight concrete with strength qualities of structural concrete, self-compacting (it depends on the compaction rate of construction), direct finish and with good thermo insulating properties.

Basic requirements are summed up in following items:

- thermo insulating properties
- structural strength at least 8 N/mm^2
- visual concrete without needs of surface finishing
- self compacting properties
- supply by ready mix

We designed and tested a mix design both in laboratory conditions and in-situ with given type of formwork (PERI) and release agent in climatic conditions expected in the time of building family houses (summer weather, 25-30°C). Composition of mix design is stated in **Table 1**.

We used pre-wetted LWA for manufacture of fresh concrete for the reason of minimizing fluctuation of rheological properties, which can be caused by uncontrolled water absorbing capacity of LWA during mixing and placing and to keep the cement matrix constantly frothed. Slump flow value of fresh concrete after mixing was 65 cm (**Fig 1**). Considering low volume weight and in spite of pre-wetting LWA we assumed, that the concrete will not be pumpable (high water absorbing capacity of LWA under high pressure during pumping, difficulties in keeping constant structure of concrete), therefore concrete was transported from truck mixer into formwork in the skip (**Fig 2**).

Tab. 1 Composition of mix design

	kg on 1m^3
LWA 4-8 and 1-4mm	1,25 m^3
CEMI 42,5 R	380 kg
Admixture (slag)	120 kg
Superplasticizer	3 l
Foaming agent	2 l
Water	140 l

Fig. 1 Measuring of rheological properties at the building site (Slump Flow test)

Fig. 2 Placing frash concrete into formwork

3 Hardened concrete

At the design stage we mixed several mix designs with dry volume weight from 850 kg/m^3 to 1100 kg/m^3. Relation between these volume weights and compressive strength is stated in **Fig 3**. Typical compressive strength of light weight concrete (measured in the course of tests) is 8 N.mm^{-2} with dry volume weight 970 kg/m^3. **Fig 4** shows development of dynamic elasticity modulus (determined with non-destructive pulse ultra sonic method) of test samples stored in water environment and samples stored in laboratory conditions (20°C, low relative humidity). Values are compared to values of static elasticity modulus. **Tab 2** states measured values of heat conductivity coefficient measured at test specimens sampled in the course of casting concrete into formwork. Static elasticity modulus of this concrete is 5.8 GPa.

In the course of experimental casting we encountered a problem of keeping constant volume of frothing of cement matrix. As we mentioned above, we frothed the mix at 20% by volume. Figure 6 shows possible results of over frothing of cement matrix. In this case the limit was exceeded by 11% by volume. Fresh was very unstable and homogeneity in formwork was disrupted. The layer of mastic cement did not form at the boundary with the formwork, either. For these reasons we closely observed correct dosage of not only frothing admixture but also mixing water and pre-wetted LWA during placing. We measured values of volume weight of fresh concrete very carefully not only after mixing but also after transport and during casting.

Tab. 2 Measured values of heat conductivity coefficient

	λ [W.m^{-1}.K^{-1}]
1	0,2655
2	0,2243
3	0,2265
4	0,2235
5	0,2355
6	0,2458
7	0,2541
8	0,2344
9	0,2587
10	0,2611
average	**0,2429**

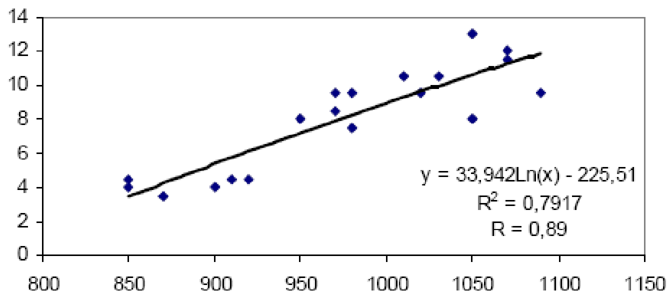

Fig. 3 Development of compressive strength in time up to 180days from mixing

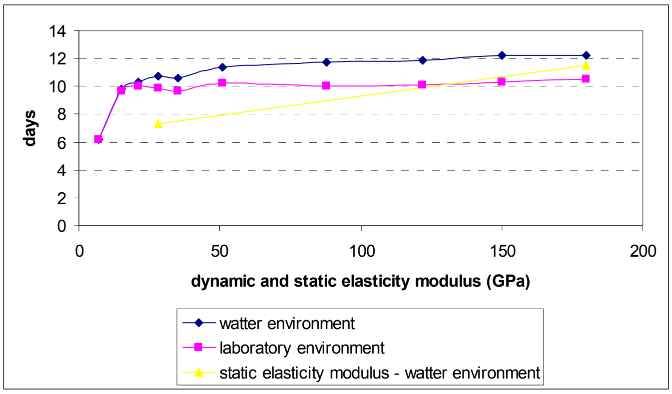

Fig. 4 Development of dynamic and static elasticity modules in time

4 Properties of concrete stored in corrosive environment

This type of concrete was studied also with respect to durability in corrosive environment. Samples were stored in selected types of corrosive environment for the period 180 days, in particular solution of sulphates of concentration 34600 mg/l, solution of magnesia of concentration 10 000 mg/l and water with corrosive carbon dioxide of concentration 50 000 mg/l. Compressive strength and value of pH were determined and X-ray diffraction analysis made after 180 days. **Tables 3 and 4** show the results.

Tab. 3 Physico-mechanical properties of concrete placed in corrosive environments – part I

Environment	Volume weight		$R_{c,cu}$
	28 days	180 days	180 days
	[kg/m^3]	[kg/m^3]	[N/mm^2]
CO_2 - 1	1060	976	11,4
CO_2 - 2	1055	978	12,7
CO_2 - 3	1082	937	12,5
SO_4^{2-} - 1	1064	1092	9,7
SO_4^{2-} - 2	1060	1062	11,6
SO_4^{2-} - 3	1103	1068	13,1
Mg^{2+} - 1	1058	1059	13,1
Mg^{2+} - 2	1064	1112	10,9
Mg^{2+} - 3	1093	1072	13,7

Note: Variation of strength is considered with respect to referential test samples stored in water for 180 days, variation of volume weight is considered with respect to volume weight at the age of 28 and 180 days.

Changes of volume weights after 180 days of storage samples in water with corrosive carbon dioxide were about -9.57%, changes in solutions of sulphates and magnesia did not exceed 1%. Loss of 9.75% weight in water environment with CO_2 is explained by change of portlandite $Ca(OH)_2$ to calcium carbonate $CaCO_3$ and then to calcium hydrogen carbonate, which is easily soluble in water and washes out of concrete. This phenomenon is apparent form X-ray analysis.

Changes of compressive strength were -10.36% in magnesia solutions, 12.95% in watter with corrosive carbon dioxide and -18.18% in sulphates. This concrete is not resistant to environment class XF4 or XA3. It can be used for structures protected from penetration of corrosive chemicals.

Tab. 4 Physico-mechanical properties of concrete placed in corrosive environments – part II

	Average			Variation	
Environment	Volume weight 180 days	Difference volume weight	180 days	Compressive strength	Volume weight
	[kg/m^3]	[kg/m^3]	[N/mm^2]	[%]	[%]
CO_2 - 1	1082	-102	12,2	-12,95	-9,57
CO_2 - 2					
CO_2 - 3					
SO_4^{2-} - 1	1074	-2	11,5	-18,18	-0,16
SO_4^{2-} - 2					
SO_4^{2-} - 3					
Mg^{2+} - 1	1081	9	12,6	-10,36	0,86
Mg^{2+} - 2					
Mg^{2+} - 3					

Tab. 5 Results of X-ray diffraction analysis

Environment	Minerals contained	pH
CO_2 1)	Portlandit, ortoklas,ettringit, β silica, kalcit, β cristobalit, biotit, vaterit	8,93
CO_2 2)	Portlandite, orthoclase, etringit, β silica, limestone, β cristobalite, biotit, vaterit	11,07
SO_4^{2-} 1)	Portlandite, orthoclase, etringit, ß silica, limestone, ß cristobalite, biotit,	10,93
SO_4^{2-} 2)	Portlandite, orthoclase, etringit, ß silica, limestone, ß cristobalite, biotit, gypstone	11,06
Mg^{2+} 1)	Portlandite, orthoclase, etringit, ß silica, limestone, ß cristobalite, biotit	8,89
Mg^{2+} 2)	Portlandite, orthoclase, etringit, ß silica, limestone, ß cristobalite, biotit, chrysotile	11,42

Note: 1) sample from the surface
2) sample from the depth of 20 mm,

Fig. 5 View of finished wall

5 Conclusions

Experimental placing proved positive utilization of expanded clay thermo insulating concrete. Frequency of test of both fresh and hardened concrete was higher during all the time of placing. On the basis of these tests we can confirm that it is possible to manufacture expanded clay thermo insulating concrete of defined properties with no major variations, however, only on condition of increased attention in all production steps. The developed mix-design is now applied for construction of family houses.

The advantage of this concrete is the possibility of use of secondary raw materials as active additives, namely fly ash or micronized slag and ultra fine additives like microsilica, metakaolin and micronized lime stone. Admixtures used are polycarboxyl based superplasticizers and foaming agents.

The way of mixing of this concrete is special: light-weight aggregate is recommended to be pre-wetted either in the mixing device by batching LWA and water (and adding the rest of materials after a while) or before the process of mixing (in the store or similar). Pre-wetted LWA gives higher stability of rheological behavior of fresh concrete and foaming of cement matrix is easier to control.

Expanded clay thermo insulating concrete can be placed with skip and crane; however, it cannot be pumped. The period of workability is between 60 and 90 minutes depending on environmental conditions (namely weather). Requirements of application of this material are the same as with common concrete including the necessity of curing.

Acknowledgment

This outcome has been achieved with the financial support of the Ministry of Industry and Trade of the Czech Reublic, MPO FI-IM5/016 „Development of light-weight high performance concrete for monolithic constructions and for precast elements" and with the financial support of project the Ministry of Education, Youth and Sports of the Czech Republic, project No. 1M0579, within activities of the CIDEAS research centre.

References

[1] Hela, R., Hubertova, M., Klečka,T. 2006 Lightweight Self Compacting Concrete (LWSCC) in the Ready Mix, The 6th International Symposium on Cement and Concrete, CANMET/ACI International Symposium on Concrete Technology for Suistanable Development, XI´ANChina 2006, str.1381 – 1388, ISBN 7-119-02249-0.

[2] Hubertova, M. 2007 Lightweight self compacting concrete used in SK Slavia Prague stadium. BFT Betonwerk + Fertigteil-Technik; Concrete plant + precast Technology. 2007. 2007(12). p. 4 - 13. ISSN 0373-4331.

[3] EFNARC, 'Specification and Guidelines for Self-Compacting Concrete', Surrey United Kindom 2002, ISBN 0-9539733-4-4, www.efnarc.org.

[4] Liapornews 2/2005 Liapor GmbH Pautzfeld; www.liapor.com.

[5] Liapornews 1/2008 Liapor GmbH Pautzfeld; www.liapor.com.

[6] Liapornews 3/2007 Lias Vintířov, Lehký stavební materiál k.s.; www.liapor.cz.