ULTRA LIGHT WEIGHT CONCRETE – A NEW BOON TO THE FIELD OF CONSTRUCTION: A REVIEW

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Abstract - *Ultra light weight concrete is developed aiming the application in monolithic buildings, (no insulation layer). Which expedite the recycling process and construction stages. In the development of ultra light weight concrete resources used light weight aggregate (LWA), admixtures, binders. The main aim for the production of ultra light weight concrete , provide high load bearing capacity and good thermal insulation. The excessive over heating during hydration is minimized by the addition of binders. The compressive strength attained by concrete in 28 days is about 10-20 N/mm2, dry density of the concrete is about 600-700 kg/m3, thermal conductivity is about 0.12 w/(mk) and provides a moderate mechanical property. The dynamic thermal characteristics of a monolithic structure of Ultra Light Weight Concrete were compared to conventional concrete structure. The contribution lies in the subsequent development and application of a simulation strategy for predicting energy and comfort performance of ULWC on the whole building level.*

Key Words: Ultra-light weight concrete, monolithic building, thermal insulation, compressive strength, dry density.

1. INTRODUCTION

The conventional building concept comprises of constructing "sandwich-type" elements that consist of structural bearing and insulating sections, in order to fulfill the building's energy efficiency requirements. Generally used types are polystyrene, mineral wool fiber or air, provide insufficient thermal insulation. With monolithic building concept, the need for an insulation layer could be overcome by developing a building material that could full fill the requirements of sufficient mechanical properties and thermal insulator at the same time. The monolithic building concept would give the architects and structural engineers more possibilities in designing and constructing various buildings and could potentially reduce building costs and facilitate the recycling process. As the thermal conductivity of concrete is mainly governed by its density only. Other types of concrete with very low thermal conductivity, such as foam or autoclaved concrete, are not possessing sufficient mechanical properties to act as a load-carrying member. The type of concrete that falls under the density (lower than 800 kg/m^3) class has been developed recently in the Netherlands, and is known as "Warmbeton" or ultra-lightweight aggregates concrete (ULWAC). The prefix ultra means superior properties.

1.1 Mix Design

The light weight aggregates used here are commercially available product manufactured from recycled glass in Germany. The LWA contain a number of air pores (cellular structure) encapsulated in rather closed and impermeable outer shell. The LWA have very low particle densities, which provide a great freedom for the design of light weight concrete with desired low density. Limestone powder, with the density of 2710 kg/m^3, is used as filler to adjust the powder amount. Nano-silica (AkzoNobel), with a solid content of 50 %, density of 1.4 kg/l and a BET surface area of the silica particles of 50 m^2/g, is used here to investigate its effect. A poly-carboxylic ether-based super plasticizer (BASF) is used to adjust the workability. An air-entraining agent (Cugla), with a density of 1.05 kg/l and resin acid soaps as active agent, is applied here to adjust the density of the lightweight concrete.

1.2 Fresh state behavior of Ultra Light Weight Concrete

The slump results show that Mix A (195 mm) under S4 and Mix B (83 mm) under S2. The flow table test results, Mix A (460 mm) under F3 and Mix B (390 mm) under F2. The better workability in the case of Mix A can be explained by the fly ash incorporated in CEM II/B-V as it is known that fly ash blended cements show improved workability than other cements under the same water dosage.

1.3 The effect of cement type

The compressive strength increasing order during the curing period of 7 days and 28 days CEM V/A (S-V) 42.5> CEM II/B-V 42.5 N> CEM III/A 52.5 N> CEM I52.5N,the high strength found in the CEM V/A (S-V) 42.5 is due to the presence of slag (GGBS) and fly ash.

Table-1: properties of cement

Cement	Density (kg/m^3)	Clinker content (%)	Fly ash content (%)	Slag content (%)
CEM I 52.5 N	3180	95-100	0	0
CEM II /(B-V) 42.5N	2980	73	25	0
CEM III/A 52.5 N	3000	48	0	52
CEM V/A (S-V) 42.5 N	2870	55	23	22

Table -2: chemical composition mix

Mixture	Mix A	Mix B	Mix C	Mix D
Cement type	CEM II/ B-V 42.5 N	CEM III/A 52.5 N	CEM I 52.5N	CEM V/A (s-v) 42.5 N
Cement content (kg)	450	450	355.0	405.0
Nano-silica (kg)	0.0	0.0	40.0	45.0
Lime stone powder (kg)	0.0	0	52.6	0.0
Lwa (kg)	212.2	212.2	207.8	212.2
Water (kg)	225.0	225.0	223.5	225.0
Sp	0.0	0.0	1.0	1.0
Air entraining agent (kg)	2.25	2.25	2.25	2.25

1.4 Thermal properties

The thermal conductivities of the samples, CEM I 52.5N, CEM III/A 52.5 N , CEM II/B-V 42.5 N,CEM V/A For almost all types of cement, the thermal conductivity value ranges in between 0.10 to 0.14 W/(mk).Even after with 28 days of curing period massive changes in thermal conductivity is not experienced. It can be interpreted that thermal conductivity is not directly related to cement content.

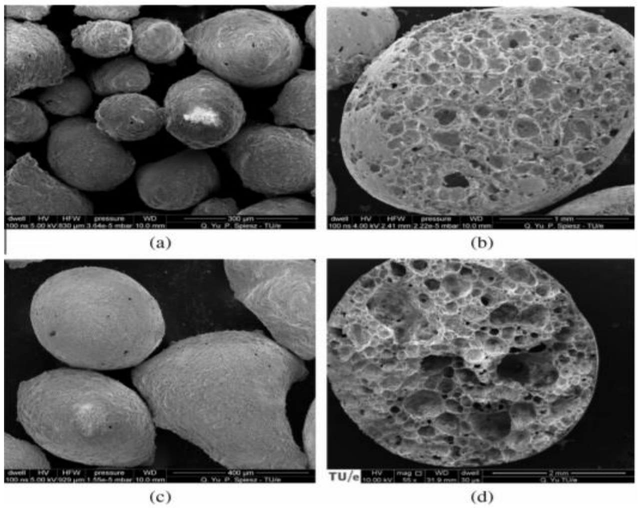

Fig -1: SEM properties of Light weight aggregate

Table-3: properties of Light weight aggregate

Materials	Bulk density (kg/m^3)	Specific density (kg/m^3)	Crushing resistance (n/mm^3)
LWA A	300	540	>2.9
LWA B	250	450	>2.6
LWA C	220	350	>2.4
LWA D	190	310	>2.2
LWA E	170	300	>2.0

1.5 The Effect Of Nano-Silica

Nano-silica have been proven to have positive effect on the mechanical properties of concrete, anti-bleeding and segregation of fresh concrete mixture and durability. Owing to their extreme fineness and high amorphous SiO_2 content, nano-silica are highly reactive pozzolonic additives. They leads to densification of paste, makes more sticky that is reduced by super-plasticizers.

1.6 Water penetration under pressure

The values of the obtained water penetration depths performed to two mixes (Mix A and B). The results show that although the designed ultra-lightweight concrete has a very high total porosity, the permeability to water under the pressure of 5 bars during 72 h is very low (11.7 mm in the case of Mix B).The water penetration difference between Mix A and Mix B can be explained by the applied cement, as the GGBS in CEM III is reacting faster than fly ash in CEM II. Furthermore, in the present study, CEM III/A 52.5 N is used in Mix B while CEM II/B-V 42.5 N is used in Mix A so the finer particles in the used CEM III contribute a further faster reaction, which leads to a denser concrete matrix.

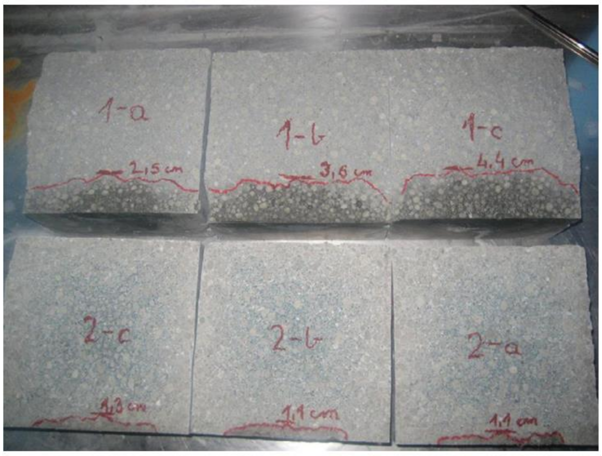

Fig -2: split surface of cubes after water pressure permeability test (Mix A, Mix B)

Table -4: penetration of water under pressure

Property	Mix A	Mix B
Maximum water penetration (mm)	35.0	11.7
Standard deviation (mm)	7.8	0.9

2. Performance Analysis

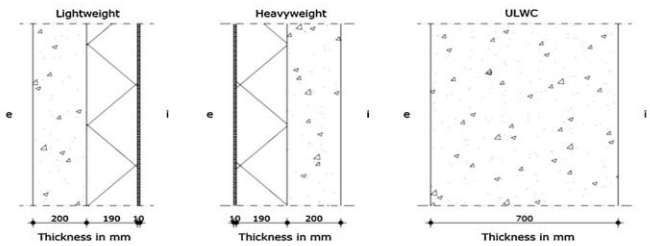

Fig -3: Three construction models

2.1 Construction temperature on a typical summer and winter day

The temperature profile within a monolithic wall of ULWC for a warm summer day. Every line represents an instant of the simulation with an interval of 2 h. There is a large temperature deviation of about 35 ˚C on the exterior side of the facade. Due to solar irradiation on the south-facing wall, The indoor surface temperature is controlled at roughly 26 ˚C.

For the winter day, In contrast to the south facade in summer, there is no direct solar irradiation at this north facade. Consequently, the external temperature fluctuates within a range of only 5 ˚ C. The temperature gradually increases to the heating set point of 21 ˚C on the inside, and shows little variation around that value during night times.

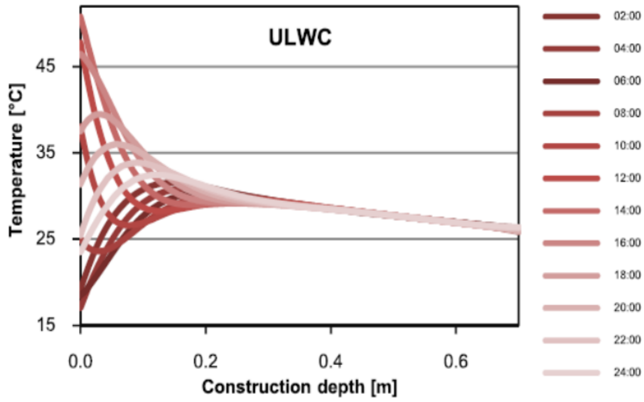

Fig -4: Temperature profile for a sunny day

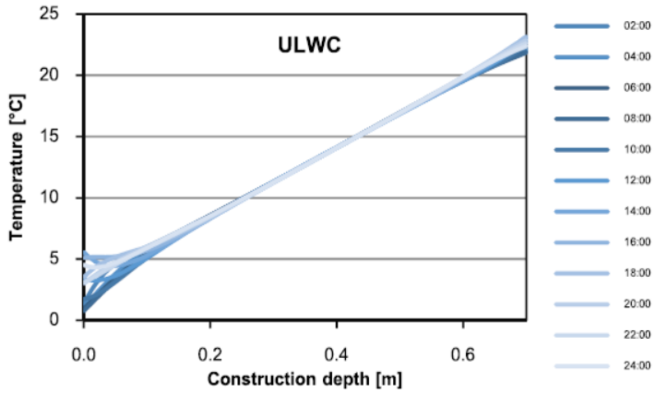

Fig -5: Ttemperature profile for a Winter day

2.2 Residential application

As a final step in the analysis, also the application of ULWC for a residential application was explored. The building geometry was assumed to be the same as for the office building, but the following differences were implemented.

The operative temperature for ULWC through out the year in the residential case is lower than the office building due to less internal gains. There are less overheating hours in the residential building than in the office building. The heat removal strategies and thermal mass, by applying ULWC in residential buildings, it is important to include sufficient options for ventilative cooling.

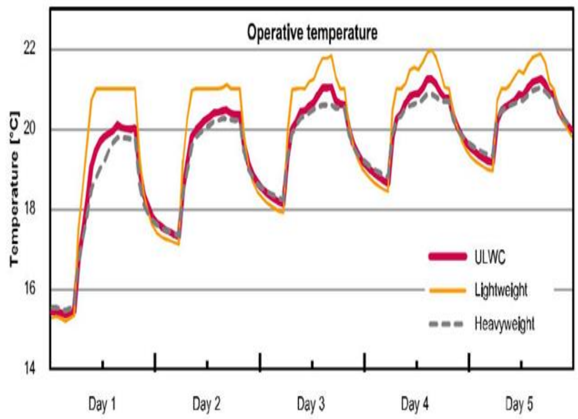

Fig -6: Thermal response for three construction type

4. ADVANTAGES AND DISADVANTAGES

Advantages

- Ultra Light Weight Concrete improves the thermal properties.
- Ultra Light Weight Concrete also promotes adequate sound insulating property.
- Ultra Light Weight Concrete reduces the over heating risk.
- Reduce the dead load.

Disadvantages

- Mixing time is longer than conventional concrete to assure proper mixing.
- Not cost effective.

5. APPLICATIONS

- In flat RCC roofs.
- Balconies and terraces.
- Replacement of brick-bat Coba (BCC).
- Green roofs.

6. CONCLUSION

The present study aims at the development of an ultra-lightweight aggregates concrete (ULWC), with good mechanical properties and a very low thermal conductivity, in order to develop a material suitable for monolithic concrete structures, thus performing as both load bearing element and thermal insulator. Based on the presented study, the following conclusions can be reached. An ultra-lightweight concrete with a dry density of about 650– 700 kg/m^3 was developed. The developed ULWC has a good workability and all the light-weight aggregates are homogeneously distributed in the concrete matrix. The developed ULWC shows a 28-day compressive strength above 10 N/mm^2, and a thermal conductivity of about 0.12 W/(m K).The developed ULWC shows an excellent resistance against water penetration.LWA do not create the alkali–silica reaction risk.

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