NEW STORAGE LATENT AND SENSIBLE CONCEPT FOR HIGH EFFICIENT CSP PLANTS

H2020 Grant Agreement Nº: 720985

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Project acronym: NEWSOL

Project full title: NEW StOrage Latent and sensible concept for high efficient CSP plants

Deliverable D3.4 - Report on new CAC-based concrete with enhanced thermal resistance

ABSTRACT

This Deliverable D3.4 is the "Report on new concretes with enhanced thermal resistance" that corresponds to Task 3.1 "High temperature sensible heat storage concrete", from WP3 "Advanced functional material development & thermal performance".

The NewSOL project in task 3.1 within WP3 aimed to study the development of two types of High Thermal Performance Concretes. The achievement of this technical objective allowed defining the concrete types that fulfill the requirement for up-scaled and used in the larger scale as the prototypes within WP6, one for the thermocline concrete tank and the other for the concrete module.

The heat storage materials to be used in a Concentrated Solar Power (CSP) plants if using molten salts as the Heat Transfer Fluid, have to endure specific thermal conditions. These conditions include high temperatures (between 290°C and 550°C) and thermal cycles to simulate the charge/discharge processes.

Two concrete types were studied:

1. High Thermal Performance Concrete for the concrete tank based on the use of calcium aluminate cement. This concrete has been developed and fully characterized by CSIC. University of Evora participated in the measurement of thermal parameters.

2. High Thermal Performance Concrete for the concrete module based on the use of Portland cement. This concrete has been developed and fully characterized by SECIL. University of Évora performed the measurement of thermal parameters.

From the results reported in this deliverable D3.4, several conclusions can be withdrawn concerning the two concrete types. Each concrete type was developed for a different prototype application, with different requirements and conditions.

High Thermal Performance Concrete for the concrete tank based on calcium aluminate cement.

The use of calcium aluminate cement as binder has been considered as a good choice for the stability of the concrete mixes. The recommended thermal aggregates for the application are basalt and calcium alumina clinker aggregates (CAT) due to their high stability and good response after suffering thermal cycles. The use of the waste material Alentejo slag as an aggregate has been reported as a sustainable alternative although with lower thermal stability that basalt and CAT.

In this case, thermal conductivity of this layer of concrete is not the critical parameter to reach an optimum performance of the thermocline tank in a whole. The mixes recommended achieve 20 MPa after 10 extreme thermal cycles (reaching the target) and 15 MPa after long-term cycles, which are considered to be enough due to their not-bearing requirements.

In addition, the selected mix with the ternary combination of aggregates has been reported as a high durability mix when in contact with the molten salts, which is reported in D4.1, from WP4 "Interaction characteristics of sensible-heat storage materials combinations". More detail information of concrete components can be found in [*M. Roig-Flores, T. Lucio-Martin, MC Alonso and L. Guerreiro, Evolution of thermo-mechanical properties of concrete with calcium aluminate cement and special aggregates for energy storage. Cement and Concrete Research 141 (2021) 106323*] and [*T. Lucio-Martin, M. Roig-Flores, M. Izquierdo , M.C. Alonso. Thermal conductivity of concrete at high temperatures for thermal energy. Solar Energy 214 (2021) 430–442*].

High Thermal Performance Concrete for the concrete module based on Portland cement.

The main conclusions are:

- The use of limestone and siliceous aggregates, although promote a higher strength and EM loss after thermal cycling, allows a production of a concrete with higher thermal conductivity;
- It was not possible to measure the impact with the use of carbon fibers on thermal properties;
- All the tested samples fulfilled the strength class needed after thermal cycling (C20/25);
- In general, is visible a stabilization of the strength loss between 25 and 50 cycles for all the tested compositions. This is most clear for all the compositions using basalt aggregates and for some using limestone and siliceous ones.
- The use of Alentejo slag on the percentages tested, lead to results not stable between 25 and 50 cycles on the compositions with limestone and siliceous aggregates.
- The compatibility of all the properties desired for the module concrete and the fulfilment of the tested KPIs, lead to recommend composition 29 as the basis for the concrete composition, with the use of Portland cement, additions, siliceous and limestone aggregates.

Some of the most promising compositions, where subjected to thermal cycling until a minimum of 150 cycles, to evaluate the thermal stress resistance with cycling.

New developments and results can lead to adjusts on the concrete composition to use on the module.

Efforts will be made also on thermal properties measurement, to check if steel and carbon fibers show impact on the improvement of thermal performance of the concretes as is expected. The measurements made with University of Évora equipment didn´t show this expected impact.