**TC 281-CCC – Carbonation of concrete with supplementary cementitious materials**

**Meeting 5, Monday 9 March 2020, 13.30-18.00**

**Guimaraes, Portugal**

School of Engineering – University of Minho, Campus de Azurem, Building nr 2

**Minutes**

**Participants**

Members (14 + 7 through Zoom): Aires Camões, Anya Vollpracht, Bei Wu (Zoom), Charlotte Thiel, Cyrill Grengg, Elke Gruyaert, Gregor Gluth, Hanne Vanoutrive (Zoom), Janez Perko (Zoom), John Provis, Luca Valentini (Zoom), Miren Etxeberria, Natalia Alderete, Nele De Belie (chair), Philip Van den Heede, Qing-feng Liu (Zoom), Ravi Patel (Zoom), Semion Zhutovsky, Shishir Mundra, Tung-Chai Ling (Zoom), Zhengfeng Zhao (Zoom), Zhiyuan Liu

Guests (4 + 1 through Zoom): Matea Flegar (University of Zagreb), Ognjen Rudic (Technische Universität Graz), Dan Geddes (University of Sheffield), Cassandre Le Galliard (University of Sheffield), Alastair March (Leeds university, Zoom)

**Welcome and short introduction of participants**

Update on membership of the TC / new members. The TC has now 94 members.

**Approval of the minutes of meeting 4, Prague, 17/09/2019**

The minutes were approved

**Feedback on the status of the working group activities by the working group chairs or their representatives / presentations related to the WG work**

**WG1**: Correlation between atmospheric carbonation and carbonation induced by accelerated testing at high CO2 concentrations (Barbara Lothenbach, Elke Gruyaert, Philip Van den Heede)

**and WG2**: Effect of SCMs on natural and accelerated carbonation of blended Portland cements (Leon Black, Stefanie van Greve-Dierfeld)

Stefanie von Greve-Dierfeld: update on the status of the paper “Carbonation of concrete with supplementary cementitious materials – A review” (sent previously by mail to the chair).

The paper was circulated to the TC members on 8/12/2019 with the request to send comments before 18/12/2019. Most members approved the paper, but also several valuable comments were received, so that it was decided to make a revision before submission. Stefanie has prepared a revised version of the literature review paper and sent this by mail to the “editorial committee” on 8 March 2020. The revision will now be screened by this committee (Barbara, Susan and Nele) before submission to Materials and structures.

Elke Gruyaert: status of the inter-laboratory test planning: first experiences, timing, … (see presentation)

The status of the interlaboratory test was presented by Elke Gruyaert. Cement has been sent to all European participants in December 2019 (non-European participants use their own cements) and the guidelines, excel worksheet and instructions were emailed to the 25 participants in January 2020. First results on fresh and hardened mortar and concrete properties were reported to the organizing committee by 16 labs; 8 other labs informed the organizing committee to start up soon the experiments.

**Reporting deadlines:**

1. Participants are asked to report to Elke as soon as the 28-days strength results are available and **at the latest by the end of May 2020**:

* **Final test procedures** followed: please fill in the Excel sheet ‘*Test proc.\_mortar and concrete’*: please do mention here the procedures as stated in the standard you follow – not the monitored conditions
* **Fresh and hardened properties**: please fill in the Excel sheets *‘mortar’, ‘concrete’, ‘aggregates’ and ‘inert structure’*
* **Temperature, relative humidity and CO2 monitoring**: Check and fill in the Excel sheet ‘*temperature, relative humidity and CO2 monitoring’*

2. Participants are asked to **report on the carbonation results (accelerated and natural tests) by the end of July 2020**, so that the results can be analysed before the next TC CCC meeting in Sheffield.

**Points of attention:**

* Please do not forget to monitor temperature, relative humidity and CO2 as mentioned in the guidelines
* Carbonation results are reported per side. In the Excel sheet this is indicated by side 1, side 2, side 3 and side 4. **Please take side 1 as the troweled surface and do indicate this once more in the comment box** so that there cannot be any confusion afterwards.
* BSI 1881-210 prescribes coating of 2 parallel surfaces to obtain an unidirectional ingress of CO2. Since coating also influences moisture transport in mortar and concrete, it is agreed **not to coat** specimens in case of the **reference samples** to be able to compare results between laboratories. Test samples following the procedure prescribed in BSI 1881-210 can be coated according to the standard.

John Provis (on behalf of Susan Bernal): outline of the paper on carbonation standards, with the volunteers for the different sections (see presentation)

The aim is to write a paper giving an overview of testing methods for determining carbonation of modern concrete. Proposed paper outline and contributors are:

* Example of standardised testing methods development: (Japan experience – Hokkaido U)
* Effect of pre-conditioning (B. Lothenbach & S. Bernal)
  + Emphasising on effect on hydration degree
  + Potential drying shrinkage
  + Degree of saturation of specimens
* Effect of exposure conditions (A. Vollpracht)
  + CO2 concentration (natural vs. accelerated)
  + Relevance of RH and T used in testing for different climates
* pH measurements (C. Thiel)
  + Different types of indicators, time when reading needs to be made
  + Relevance of pH changes in terms of durability of SCM containing concrete

**WG6**: Carbonation of alkali activated concrete (Xinyuan Ke, Gregor Gluth)

Gregor Gluth: status of activities – carbonation of concrete with high volume of SCMs (see also presentation)

40 potentially relevant papers (mostly journal articles) on alkali-activated concretes and mortars were evaluated. Of these, 27 contained analyzable carbonation data [*i.e*. contained useful data that was transferred to the database] (mostly on AAS; mostly carbonation depths *versus* time, some only computed carbonation rates); 13 could not be used (e.g., data “hidden” in X-versus-Y plots, mix-design information incomplete or internally conflicting, …).

Data from seven project reports (RWTH Aachen/ibac and Univ. Hannover) on concretes based on blended cements with a high volume of SCMs (mostly CEM III + fly ash) were transferred to the data­base. In addition, unpublished data by RWTH Aachen/ibac (3 concretes: CEM III/B, CEM II/B + natural pozzolan, CEM III/C), kindly provided by Anya Vollpracht, was included in the database. Furthermore, eleven potentially relevant papers/reports on concretes based on blended cements with a high volume of SCMs were evaluated. Of these, six contained analyzable carbonation data (carbonation depths *versus* time or only carbonation rates); five could not be used (mix-design information incomplete or internally conflicting, …).

The evaluation of the data in the database has not much progressed since the last TC meeting. A preliminary analysis suggests a correlation between *w*/MgO and carbonation rate, but this may be simply related to the GGBS content of the studied alkali-activated concretes.

**Tasks/deadlines:**

In the discussions of WG6 it was agreed that the next step will be to check the database for correctness (*i.e*. WG members will randomly check entries that were filled in by others). G. Gluth will send around an e-mail to the WG members in this regard. Subsequently, an analysis of the data will be attempted. It is planned to present the outcomes at the TC meeting in the context of the RILEM week in Sheffield.

**WG4**: Effects of combined actions: load + carbonation (Yao Yan, Ling Wang, Juan Li) (see presentation)

Philip Van den Heede: The first round interlaboratory test on carbonation in combination with mechanical load (compression mode) was initiated by only one of the participating laboratories, i.e. the Magnel-Vandepitte Laboratory. The concrete composition under investigation was a traditional Portland cement concrete with a CEM I 42.5 N cement content of 330 kg/m³ and a water-to-cement ratio of 0.60. In the test protocols it was mentioned that superplasticizer would be needed to achieve a slump of 110 mm. For the batch of concrete that was made by the Magnel-Vandepitte Laboratory with local materials addition of superplasticizer was found to be unnecessary. The highest slump class was reached from the start. A question came from the audience on whether corrections to the amount of added water were made to account for the water absorption by the sand and aggregates. This was not the case. This issue should be addressed for the follow-up interlaboratory test. In terms of sample preconditioning after casting the Magnel-Vandepitte Laboratory could not comply with the imposed test protocol. At the age of 28 days, the upper loading plates failed upon try-out of the test frames due to an insufficient thickness at the center. The loading plates were strengthened with a piece of steel with a thickness of 40 mm and stirrups. It took some time to figure out a proper modification of the test frames. It resulted in an extra 28 days of preconditioning for the samples. In the final setups manufactured by the Magnel-Vandepitte Laboratory, a load cell was in between the upper loading plate module and the concrete prisms to be able to monitor the load level at all time and make readjustments if needed. Strain gauges attached to the sides of the prisms were also being monitored. The aim was to deduce relevant loading level induced information from the strain gauge readings.

Upon applying the load (45% of breaking load) with a hydraulic testing machine, it was found that that a higher initial load was needed in order to have 45% of the breaking load in the end with the spring washer based loading plate module. This initial load amounted to 71% of the breaking load. Although only applied briefly, it could be that this initial higher load already introduces some damage that affects the carbonation resistance. Observed differences between unloaded an unloaded prisms could be due to briefly applying 71% of the breaking and not due to maintaining 45% of the breaking load afterwards. The stacking of the spring washers in the upper loading plate module should be further modified and optimized to overcome this problem. After 28 days of exposure an unloaded dummy cube was split. At the troweled surface the carbonation depth amounted to 4.6±0.9 mm while at the cast surface a carbonation depth of 3.8±1.1 mm was recorded. This was considered insufficient to clearly see a difference between unloaded and loaded samples. Therefore, it was decided to extend the exposure period with another 28 days. Thus, at the moment the test is still ongoing. In terms of monitoring the loading levels in time, the presence of the load cells was the only way to do so in a proper way. From this it could be concluded that the loading level needed to be adjusted around two times a week with ±2 kN. This kind of information could not be derived from the strain gauge readings.

**Future activities and meetings, miscellaneous**

*Future meetings:*

6th meeting + workshop (conference session): August 2020, Sheffield (UK), 74th RILEM Week, 30/08 to 4/09/2020

The RILEM standing committees would meet on Monday 31 August. Rooms are not available in the weekend. The conference will run from 1 until 4 September lunchtime. The TC special session could be organised on 3/09 or 4/09 am. The TC meeting could then take place on Friday 4/09 pm.

John had received only few abstracts dedicated to the special session. After the meeting, Nele has launched a call for authors to identify submitted abstracts that belong to the special session. Also additional abstracts can still be submitted.

The overview of abstracts in the special session at the time of sending the minutes (23/03/2020) is given below.

370 - Carbonation of mortar with supplementary cementitious materials: comparison between water, sealed and calcium hydroxide curing (Vanoutrive)

307 - Assessment of Alkali-Activated Slag Carbonation (Le Galliard)

225 - Effects of carbonation on the mechanical properties of cement pastes and mortars (Phung)

193 - Impact of carbonation on the chloride ingress in concrete with ground granulated blast-furnace slag (Vanoutrive)

165  -  Changes in performance of concrete with supplement cementitious materials on carbonation(Cheng ZHANG)

188 - A numerical method to determine the carbonation behavior of concrete based on the finite element method (Xinyu SHI)

234 - Role of the concrete cover to suppress corrosion of steel in carbonated concrete (Matteo Stefanoni, Zhidong Zhang, Ueli Angst)

277- Carbonation of unloaded and loaded blast-furnace slag concrete: damage induced by loading and changes in pore structure induced by loading and carbonation (Zhiyuan Liu)

? - Varying carbonation properties as a function of depth from the exposure surface: Role of the wall effect (Philip Van den Heede)

? - Field Survey on Carbonation and Its Relation to Re-bar Corrosion of Existing Concrete Buildings over 50 Years Old using Ground Granulated Blast Furnace Slag Cement in Japan (Kei-ichi Imamoto)

7th meeting: RILEM Spring Convention 2021 Paris, France, \*75 years celebration\*

*Review of recommendations*

We received a request of TAC to review the RILEM recommendation CPC18: measurement of hardened concrete carbonation depth. It was noticed that several points in the recommendation should be revised and decided to make such revision after the ILT.

*Feedback for RILEM*

A request was received from the Rilem Implementation Manager (RIM) Daniela to share on the RILEM bits & bobs newsletter any news, outcomes or events related to the Technical Committee (text no longer than 100 words and a picture in high resolution). It is discussed that this could be done after completion of certain deliverables such as the WG1-2 review paper and or the interlaboratory test.

**Discussions within working groups (WG1-2, WG6)**

The plenary meeting was followed by discussions within the working groups WG1-2 and WG6.

Dedicated meeting of WG3 and WG5 were postponed to the Sheffield meeting on request of the WG chairs.

**Closure**