Evaluation of Doctoral Thesis

Evaluation Author: **Ing. Libor Sitek, Ph.D.**
Thesis Author: **Ing. Iveta Nováková**
Topic: **Behaviour of Cementitious Composites Exposed to High Temperatures**
Supervisor: **doc. Ing. Lenka Bodnárová, Ph.D.**
Study program: **P3607 Civil engineering**
Field of study: **3911V006 Physical and Building Materials Engineering**

The presented doctoral thesis deals with the development of suitable methods for the enhancement of fire resistance of both the already-existing and newly-designed concrete structures. In addition to a short abstract in English and Czech, the thesis is divided into four theoretical chapters focusing on important aspects of fire protection of concrete structures, methods of fire resistance testing and behaviour of concrete at high temperatures. The practical part is also divided into four chapters which describe the experimental methods used, specify individual experiments, present and evaluate the results of experiments. Based on them, concrete mixture suitable for use at higher temperatures and/or resistant to direct fire is proposed. The practical part also pays attention to the design of a method suitable for the enhancement of fire resistance of the already-existing concrete structures. The thesis is supplemented by lists of references, abbreviations, pictures, tables and four Annexes.

a) Topicality of the theme

The doctoral thesis elaborates a very current topic of the resistance of concrete and reinforced concrete to high temperatures or fire. In particular, building structures in road and railway tunnels, underground garages and enclosed spaces can be exposed to enormous thermal loads in cases of fire, which current composites with a conventional cement base withstand with difficulties. Reducing the impact of fires on concrete structures and the passive protection against high temperatures deserve great attention due to the increasing number of accidents and damages of concrete structures caused by fire and high temperatures in recent decades.

b) Fulfilment of the goals

The aim of the doctoral thesis was the development of two methods dealing with the porous structure modification of concrete surface layers. The first method (i.e. the intentional heat treatment) is suitable for the enhancement of fire resistance of existing structures by heat treatment; the second method proposes the design of air-entrained concrete with the application of new generation of air-entraining agents suitable for fire resistance enhancement of newly-designed concrete structures. The structure design and suitable composition of concrete were proposed on the basis of carefully prepared and conducted experiments, and an extensive set of results of concrete testing during thermal exposure. The objectives of the study and the assigned tasks were fully accomplished.

c) Problem-solving procedure, results of the thesis, contributions of the PhD student

The procedure for solving the research problem was chosen appropriately. Based on detailed research and analyses of available knowledge, the PhD student proposed two experimental methods to increase the resistance of concrete to the effects of high temperatures based on modifying their pore structure. After extensive laboratory testing of individual concrete components for the resistance to high temperatures, suitable concrete mixtures were proposed for both investigated methods.

The strength, modification of the pore structure and presence of the so-called moisture clog were subsequently determined experimentally in the proposed concrete test samples. The effectiveness of both methods was evaluated according to the modified standard time-temperature curve ISO 834. The obtained results were then appropriately analysed and interpreted. It has been proven that the existing concrete structures can be improved by preheating with regard to their increased resistance to high temperatures. On the contrary, the aerated concrete with designed fire resistance properties showed only a slight improvement and more noticeable water barrier than in the case of preheated samples.

d) Significance for practice, contribution to the development of the scientific field

The PhD student contributed significantly to the research issue due to his detailed analyses and experiments which successfully verified the effectiveness of two methods used for the resistance improvement of concrete structures to high temperatures: (i) enhancement of fire resistance of existing concrete structures using moderate pre-heating with low environmental impact and zero effect on the aesthetic appearance of the concrete surface and (ii) design of new aerated concrete with improved temperature and fire resistance using air-entraining agents of new generation. The broad scope of research as well as the knowledge gained by the student thus justifiably contribute to the development of this scientific field and should not be overlooked by the professional public.

e) Formal arrangement of the doctoral thesis and its language level

The doctoral thesis is relatively extensive (182 pages without annexes); however, it is very carefully and clearly elaborated. The structure of individual parts is clear, the chapters follow each other logically. The extensive set of results is precisely processed and correctly interpreted. The thesis contains 244 references to the literature and internet resources used, which I consider appropriate due to the breadth of the researched issues. The content and scope of the work meet all requirements for a doctoral thesis. The language skills of the PhD student seem to be very good; however, as a non-native English speaker I cannot fully assess the language proficiency of the work.

f) Other findings and critical comments

Despite the careful elaboration, the thesis contains some minor shortcomings and errors. In the following text, I have listed some of them in points. I have also asked a supplementary question. The remarks are intended to help the PhD student in her future scientific career and do not reduce the high quality of the submitted work.

- Page 13: The designation of **fire** as one of four classical elements is rather a philosophical than scientific term related to the ancient Greek philosophy. A more appropriate scientific expression would be that fire is rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products (see e.g. Wikipedia).
- Page 24: Equation (1) is missing.
- Simultaneous use of tables and graphs created from the data in tables is superfluous (for example, Tab. 25 and Fig. 87). One of them is enough to express the necessary dependencies. I am personally more inclined to use the graphic form that is more illustrative.
- Interpolation of the measured points by trendlines is sometimes misleading; unless a clear dependence is given based on the physical nature of the phenomenon (e.g. linear, exponential, etc.) and the interpolation of points would be thus avoided (e.g. dependences in Fig. 87 should probably not be linear, similar as the meaningless polynomial trends of dependencies in Figs. 89 or 91).

- Fig. 102: Description of photos is obviously incorrect. I assume that the reference sample should be described under the letter c).
- The connection between points in some graphs lacks the physical meaning (e.g. Figs. 105 - 108 or the weight loss in Fig. 124). I recommend using a bar graph in these cases.
- In the printed form, some images are too small and thus difficult to read (e.g. Figs. 19 - 21, Figs. 26, 37, etc.).
- Decimal points should be used consistently in the English text instead of decimal commas.
- Use chapter titles in the work consistently (since Chapter 5, the word "CHAPTER" is superfluous in the title).
- **Additional question:** If the concrete structure is already damaged by high temperatures, in which cases would you decide to repair the damaged structure and what method for removing the damaged layers would you use?

g) Overall evaluation

The submitted work completely meets the requirements for a doctoral thesis in the field of study. The PhD student demonstrated excellent knowledge of the researched issues and the ability to use the obtained knowledge as well as available modern techniques to meet all objectives of the PhD thesis. Due to the high level, I recommend the evaluated work for defence. After the successful defence, I fully agree that the PhD student will be awarded a doctoral degree.

In Ostrava, November 30, 2020

Ing. Libor Sitek, Ph.D.