

## Opinion of the dissertation

**Thesis author:** Iveta Nováková

**Thesis title:** Behaviour of cementitious composites exposed to high temperatures

**Thesis title:** Brno University of technology, Institute of technology of building materials and components

**Reviewer:** Pierre Pimienta, pierre.pimienta@cstb.fr

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### Actuality of the dissertation topic

Controlling the sensitivity of concrete to its spalling behaviour during fire exposure is one of today's major issues in the design and construction of concrete structures. Several fire accidents, as for instance in tunnels, have demonstrated that spalling of concrete can have serious structural and economic consequences. Developments in concrete mix design have led to new types of concrete such as high strength concrete, which, despite an increased structural performance, have also shown a higher sensitivity to spalling. However, until now, the phenomena is not fully understood. The 2 most used methods to reduce the risk of spalling are to add polypropylene fibres (PP fibres) in the concrete mixes and to shield the structures with fire protection materials. However, these solutions are costly and sometimes difficult to apply. The first one (PP fibres) is applicable only on works to be constructed and not to existing structures. The research presented in this doctoral thesis proposes to study 2 new and innovative technics to reduce the risk of spalling, the IHT (Intentional Heat Treatment) and the air-entraining agents addition. The first technic, IHT, is designed to be applied on existing structures.

Rating:

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### Meet the objectives of dissertation work

The presented research work concerns the development and characterization of 2 new techniques which aim to reduce spalling risk in concrete structures when exposed to fire. The document presents in a more developed way the study carried out on the first solution (IHT). This review therefore focuses primarily on this work.

The work program is well organized in several phases (characterization of constituents at high temperature and 4 series of tests on mortar and concrete). It is very appreciable that a large number of different test techniques have been used: mechanical characterization, MIP (mercury intrusion porosimetry), TGA-DTA, X-ray diffraction, ... This was certainly be possible by the realization of this work

in 3 laboratories (Brno University of Technology, Czech Republic, Wismar University, Germany, University and Innovation Center, Iceland).

At each phase, the results of the tests are examined very carefully, and conclusions are drawn. This forms the basis for the work in the next phase. The followed work program is therefore logical.

All the work carried out makes it possible to write that the IHT technique is certainly promising. However, further work is needed to evaluate this solution more precisely. We can cite in particular: comparative spalling large scale tests in better agreement with the reference techniques and performance durability tests as carbonation rate and chloride penetration test (see more details in the next section).

The study carried out on the second solution, the addition of air-entraining agents, is limited and do not allow to conclude completely on its efficiency.

Rating:

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### **Problem solving procedure - processing methods**

As written before, the research program on the IHT technical solution is well organized in several phases (characterization of constituents at high temperature and 4 series of tests on mortar and concrete).

The characteristics of the constituents (cements and aggregates) at high temperature were first studied in detail. This is not always done in comparable studies. The obtained results allow a more rigorous analysis of the ones determined subsequently on mortars and concretes. This is much appreciated.

The work performed in Series 1 is particularly comprehensive. Of particular interest is the study of the effect of the exposure to water.

The available equipment did not allow to properly evaluate the effectiveness of the 2 techniques studied (IHT and air entrainment) to reduce the risk of concrete spalling. The 3 main weaknesses are the following. 1/ The applied temperature curve is lower than the standard reference curve ISO 834-1. The temperature increases during the first 10 minutes (a very important parameter for concrete spalling) is about twice lower. The thermal exposure may therefore be less severe. 2/ The size of the samples is a bit too small. 3/ In order not to risk damaging the furnace with specimens with the higher risk of spalling, the tests were only carried out on the treated specimens. Therefore, this program did not allow comparison of the behavior of the treated specimens with the untreated reference specimens. It therefore does not allow the effectiveness of the 2 treatments studied to be proven in an indisputable manner.

The Series 1 tests showed the significant influence of water exposure on the porous structure and mineralogical composition of the specimens exposed to IHT. It would therefore have been interesting to test the spalling behavior of specimens IHT treated and exposed to water to complete the validation of the IHT treatment.

The durability of concrete structures is a major issue, especially in the case of large structures exposed to the outdoor environment. Thermal exposure can impact the microstructure (porosimetry, micro-cracks, cracks ...) and the mineralogy of the concretes in particular close to the exposed surface and then their durability. The impact of the IHT technique on concrete structures durability has been studied by means of MIP, TGA-TDA tests during series 1. It was concluded that its application does not have negative impact on the durability of concrete. Although these characteristics are very relevant tools for the assessment of durability, the latter cannot be considered sufficient to prove indisputably that the

IHT treatment does not have an impact on durability given the economic and strategic issues that may be at stake. Thus, larger testing program including performance tests as carbonation rate and chloride penetration is needed to contribute to its complete technical assessment.

It should be noted that even in the case of the longest treatments (450 min in series 1), it is extremely likely that the area of the specimens most impacted is the one close to the exposed surface (largest gradients). The reviewer did not find any information on the location of the specimen collection for the MIP and TGA-TDA tests. We can certainly conclude that these samples are representative of the average characteristics of the concrete over the entire thickness of the specimens and not the area that is likely to have been most affected. It should be noted that durability risks such as carbonation, chloride penetration, freeze-thaw resistance are strongly related to the microstructure and mineralogy of the concrete near the exposed surface.

The presented analysis integrates the examination of numerous comparisons of results depending on different parameters. However, the number of individual results used for the determination of each given value was not found. Similarly, the dispersion of the results and the measurement uncertainties are not given. We can certainly conclude that the values given are the result of tests carried out on single specimens. In this case, we cannot know if the differences are significant when they are small (for example, when they are equal or lower than 5%).

Rating:

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### **The importance of dissertation work for practice and for the development of the field of science**

The bibliographical study has been carefully carried out and is clearly written. It will be useful to all those who are beginning studies on the behaviour of concrete exposed to high temperatures and fire.

The main research work presented concerns the development and characterization of a new technique for the protection of concrete structures, the IHT (Intentional Heating Treatment). This technique appears to be a promising solution. If this technique is conclusive, it could be of interest to professional players in concrete construction, particularly for underground structures.

In this context, a large number of research tests using different techniques have been performed. They were carried out on concrete constituents (aggregates, cements), mortars and concretes. The results obtained and the analysis carried out are of high scientific interest.

Rating:

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### **Formal arrangement of the dissertation and its language level**

The dissertation is detailed, precise and well argued.

Figures and tables are clear and easy to read.

Rating:

<input checked="" type="checkbox"/> excellent	<input type="checkbox"/> above average	<input type="checkbox"/> average	<input type="checkbox"/> below average	<input type="checkbox"/> weak
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## Evaluation of publishing and other activities of the doctoral student

Iveta Nováková has published more than 25 papers since 2014. This shows a very important scientific activity on many research areas on the concrete material (behavior at high temperature, recycled aggregates concretes, basalt fibers, ...).

She carried out its work in four laboratories in four different countries: Brno University of Technology, Czech Republic, Wismar University, Germany, University and Innovation Center, Iceland and Arctic University of Norway, Norway.

During these last 6 years, she has therefore been confronted with and acquired a rich experience of various working methods and cultures, scientific fields and experimental techniques.

The work presented in the thesis appears to be just one part of the body of work carried out since 2014. Iveta has contributed to more than 15 projects and seems to have been involved beyond what is generally expected of a doctoral student (as for example: preparation of research grant applications).

Rating:

<input checked="" type="checkbox"/> Excellent	<input type="checkbox"/> above average	<input type="checkbox"/> average	<input type="checkbox"/> below average	<input type="checkbox"/> weak
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## Notes and comments on the work text

As written before, the dissertation is detailed, precise and well argued. Figures and tables are clear and easy to read.

Some remarks are however given below.

In the large section II "Experimental part", bibliographical references are sometimes missing when results from the literature are given.

The term "Fire Resistance" is defined on page 19. This term characterizes the very complex behavior of parts of construction works exposed to fire. It depends on multiple behaviors as mechanical characteristics changes, deformation incompatibilities, load transfers, spalling, ... Subsequently, the term is sometimes used in paragraphs dealing with only one of these behaviors (as mechanical characteristics changes with increasing temperature or spalling behavior).

The term "Moisture clog" was defined by Shorter & Harmathy (1961). It corresponds to an area of concrete saturated with liquid water during exposure to high temperature. This term is not always used exactly in the thesis. In particular, it appears in graphs showing temperature gradients as a function of time. It is associated most of the time with a temperature gradient plateau. These observations are not proof of the presence of the moisture clog.

## Conclusion

During the last 6 years, Iveta Nováková has carried out a very important research activity within the framework of numerous projects and in several fields. This reflects a great involvement and maturity.

The work presented in the thesis appears to be just one part of the body of work carried out.

In this thesis, the proposed IHT technique is an original and innovative solution to improve the fire resistance of existing concrete structures.

The work program is well organized. A large number of different test techniques has been performed. An important work of analysis of the results has been carried out.

At the final step, test series n° 4, we would have liked to see a more complete experimental program in order to evaluate the effectiveness of the IHT technique in greater detail.  
However, this technique appears promising. This work should be continued in the framework of future projects in order to conclude on its effectiveness and efficiency.

Applicant by preparing a dissertation proved eligibility for independent creative scientific work in the sense of § 47 of Act No. 111/1998 Coll. on Higher Education Institutions and Amendments to Other Acts.

I recommend that the dissertation is accepted for defense and so in the event of a successful defense of the

Iveta Novakova

awarded the academic title " Doctor " (abbreviated to "Ph.D." after the name).

Date: 10/01/2021

Opponent's signature: Pierre Pimienta

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