



Opponent's review of the Doctoral Thesis

Candidate Barbora Píšová, MSc.

Title of the doctoral thesis The use of spray-applied waterproofing membrane in underground construction

Branch of study Building and Structural Engineering

Tutor Prof. Ing. Matouš Hilar MSc., Ph.D., CEng.

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Topicality of the doctoral thesis theme

Commentary:

The thesis deals with waterproofing in tunnelling, an actual ongoing issue in underground construction, but partly also in scientific and building companies controversially discussed topic. A functional waterproofing has positive impact on durability of the structures. There are various types of waterproofing and this thesis deals with one of them, produced directly on building site by spraying. The technically easy and fast application, low material consumption and low maintenance requirements and easy repairs sound promising to the economical and sustainability beneficial impact. The bonding property of the sprayed membrane introduces the potential to reduce the overall concrete thickness, and less concrete consumption equals to lower use of portland cement and therefore less CO₂ and greenhouse gas production that would for sure have positive impact on the environment, a topic also highly actual.

In summary, the presented doctoral thesis can be classified as highly up-to-date.

excellent above average average below average poor

Fulfilment of the doctoral thesis objectives

Commentary:

The objective of the thesis was to investigate comprehensively a relatively new type of waterproofing in underground construction that has not yet been widely used. Relevant literature has been reviewed and gaps in the current knowledge of the composite lining with the use of the sprayed waterproofing membranes have been identified. Site observations have been used to recognize interrelations between the theoretical background and praxis and comparison of applications resulting in suggestions of improvements. Numerical modelling has shown the importance of the bonded/de-bonded scenario and recommendations were developed.

The objective of the thesis has been fulfilled in an excellent way.

excellent above average average below average poor

Research methods and procedures

Commentary:

The dissertation specified in the introduction the problem and the objectives of the thesis. For the

basis of the topic, the dissertant reviewed relevant Czech and British standards and evaluated them with regards to the design of the tunnel linings with the sprayed waterproofing membranes. She identified the State-of-the-art and reviewed and evaluated investigations carried out by others with regards to the use of the sprayed membranes within a composite lining. She relates the use of the sprayed membrane to the use of sprayed concrete for permanent structures and therefore presents history and development of the sprayed concrete tunnel linings as permanent. The applicant also presents tunnel lining design according to various tunnelling methods and tunnel lining design concepts. She presents examples of practical use of the sprayed waterproofing membrane on selected projects with remarks and lessons learnt.

The doctoral candidate thereafter identifies each element of the composite lining (primary lining - sprayed membrane - secondary lining) and describes function of each element with particular emphasis on identification of water path within the primary lining and properties and production of the sprayed membranes. Finally, the PhD student investigated the behaviour of the composite lining based on numerical modelling and potential failure modes.

Overall, the doctoral student utilises three research methods: literature review, site observations and numerical modelling. The solution methods / research methods and procedures have been well chosen adequately to the character of the task.

excellent above average average below average poor

Results of the doctoral thesis – dissertant's concrete achievements

Commentary:

The doctoral thesis has achieved its objectives, investigating the use of the sprayed membranes in underground construction from the theoretical and practical point of view and highlighting the advantages and disadvantages of the system. The dissertant has explained the interrelations of the system, from the permanent primary lining to the secondary lining design. She has also shown that the use of the permanent primary lining in the Czech Republic is not clear and that it could be used as long as sufficient durability of the sprayed concrete is achieved.

Furthermore, the applicant has described the elements of composite lining and studied its behaviour by means of numerical modelling and showed that the interface bond through the sprayed membrane has significant impact on the tunnel lining design and that an effective composite lining with a thin secondary lining can be designed only if the bond can be relied on.

The dissertant concludes that since the bond cannot be fully relied on, the secondary lining is recommended to be designed for both cases with and without bond through the sprayed membrane. He has found out that it is not conservative to carry out a tunnel lining design with the use of the sprayed membrane and assume full slip of the interface since this may have detrimental impact onto the water-tightness of the membrane. The dissertant suggests that the design of tunnel linings with the use of the sprayed waterproofing membranes can be changed during construction based on observations of real water inflow during the excavation and the primary lining installation.

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Importance for practice and for development within a branch of science

Commentary:

Introduction of new solutions into practice costs energy and for their successful application, uniform, systematic and scientifically proven approach shall be developed.

Designers and contractors often introduce new solutions based on their subjective knowledge and experience, but the lack of systematic scientific approach often leads to self-interpretation of diverse published data and manufacturer's recommendations. Potential material, time and cost savings were the major motivations to deeply look into the problem of the use of the sprayed membranes. Construction, more than any other scientific disciplines, is closely connected to the practice.

The doctoral student summarized available data related to the topic and evaluated them based on her practical and theoretical experience that is considered highly beneficial to the tunnelling industry. From the practical point of view, the use of sprayed membranes can be faster and easier even though there is a higher risk of quality since it is a product manufactured directly on site. The dissertant connects well the practical aspects of the use of the sprayed membrane and the theoretical background. After reading this thesis, each party of the construction process (client, designer, contractor) can make informed assesment on whether this system would be suitable for their project or not.

From the safety point of view, especially when remotely controlled spraying robots are used, working at height is significantly reduced. Maintenance requirements should be lower due to the easier localization of the potential rupture and point of water ingress. The economical aspects have not been investigated thoroughly in the thesis, however it has been understood that the final costs depend on the amount of pre-treatment of the primary lining in order to stop the active water ingress and the thickness (material consumption) of the membrane.

excellent above average average below average poor

Formal layout of the doctoral thesis and the level of language used

Commentary:

The doctoral thesis is factually correct, properly organized, written clearly, well structured and understandable. The cadence of the text is fluent and the chapters follow one another in logical sequence. The quality of the photos and graphics is high and the references are well cross-referenced.

The English language is on a very high level, almost free of spelling mistakes and errors - that ist especially remarkable, since the applicant is not an English nativspeaker.

The thesis is delivered in the form usual for a PhD thesis, it fullfils the expectations of doctoral thesis entirely.

excellent above average average below average poor

Remarks

The dissertant's thesis is mainly focused on the British and Czech standards, normatives and examples of the use of the sprayed membrane in the UK and the Czech Republic, with only a few references to German or Austrian standards. Given the language capabilities of the doctoral student, it is to be regretted that the dissertant has not extended the research even into Germany and Austria. The economical aspects of the use of the sprayed membranes could have been investigated deeper, since any innovation is only innovative when commercially successful.

1. What was the reason for you to choose this topic?
2. You demonstrate on one example a comparison of economical aspects of the use of sprayed membrane compared to the plastic sheet membrane. Could you generalise that?
3. You found out that one of the biggest advantages of the sprayed membrane is the possibility to use sprayed concrete secondary lining. Would that be possible/acceptable in the Czech Republic?
4. You state that there is a risk of loss of water-tightness of the membrane when failed in cohesion. What would be the remedial works?
5. Would you consider the use of the sprayed membrane on your next project?
6. How do you evaluate the aging behaviour of the sprayed membrane, respectively which behaviour do you expect?

Final assessment of the doctoral thesis

The submitted thesis is in the required scope, the content has 136 pages. The thesis meets the basic requirements required for similar works (title, content, Czech and English abstract, introduction, essay, conclusion, references to used literature, etc.).

The presented doctoral thesis deals with the use of sprayed waterproofing membranes in underground construction. Traditionally, prefabricated waterproofing materials (usually PVC foils) are used to ensure the watertightness of underground structures, but there is the possibility of using waterproofing materials manufactured directly on site (sprayed waterproofing membranes), the application of which has recently expanded considerably. In the Czech Republic, the technology of sprayed waterproofing membranes has been used to a limited extent.

The introductory chapter presents basis of the topic. For this purpose, current requirements and specifications are evaluated with regards to the design of the tunnel linings with the sprayed waterproofing membranes. History and development of sprayed concrete tunnel linings with focus of development of permanent primary lining, tunnel lining design according to various tunnelling methods and tunnel lining design concepts are presented in Chapter 3. In Chapter 4, lessons learnt from practical use of the sprayed waterproofing membrane on selected projects are presented. In Chapter 5, each element of the composite lining (primary lining - sprayed waterproofing membrane - secondary lining) is identified and its function described with particular emphasis on identification of water path within the primary lining and properties and production of the sprayed waterproofing membranes. In Chapter 6, behaviour of the composite lining is described based on numerical modelling and potential failure modes. Chapter 7 summarizes the results of the work, provides recommendations and suggests further research of the topic.

In general, I have no fundamental objections to the submitted thesis, in my opinion the doctoral thesis meets the basic requirements for similar work. It shows that the dissertant has a good overview of the problem, which is partly due to the dissertant's work on the Crossrail project, where she gained a valuable practical experience. I consider the achievements of the thesis to be beneficial for underground structures not only in the Czech Republic.

In summary: The presented thesis fulfilled its objectives and meets the prescribed requirements. In dealing the offered topic, the author has proved excellent knowledge and experience in multiple interdisciplinary scientific fields. Besides of that the PhD student has also demonstrated independence and ability to analyze and solve interdisciplinary problems thoroughly.

Summary: This dissertation is highly innovative, presents new results in science and practice on a high level and therefore I recommend – after fulfilling the all requirements of abilities involved in the PhD study program in the branch of Civil Engineering and after passing successfully the defense of the thesis – the student

Barbora Píšová, MSc

awarding the academic title of

DOCTOR, abbreviated as PhD.

in Civil Engineering.

Following a successful defence of the doctoral thesis I recommend the granting of the Ph.D. degree

yes no

Date: 25.02.2020

Opponent's signature:.....