CZECH TECHNICAL UNIVERSITY IN PRAGUE
Faculty of Civil Engineering
Department of Science and Research
Thákurova 7, 166 29 Prague 6, Czech Republic

e–mail: hamarova@fsv.cvut.cz tel.: (+420) 2 2435 8735

Review of Thesis

submitted in partial fulfilment of requirements for promotion to associate professorship

Specialization: Teorie stavebních konstrukcí a materiálů

Applicant: Ing. Jan Fořt, Ph.D.

Reviewer: Prof. Dr. Dipl.-Min. Willi Pabst

Thesis title: Development and assessment of sustainable cement- and geopolymer composites

Importance of topic of thesis

Comments: The habilitation thesis of Ing. Jan Fořt, Ph.D., entitled "Development and assessment of sustainable cement- and geopolymer composites", is a highly timely and topical contribution toward the solution of a fundamental problem that has immense impact on society and mankind as a whole, viz. the problem of reducing carbon dioxide emissions from the inorganic binder industry. In particular, it is reported that the production of Portland cement alone is resonsible for 15 % of total industrial energy consumption and up to 8 % of total carbon dioxide emissions (the major volume originatiing from limestone calcination). Therefore the candidate's work focuses on using waste materials, e.g. waste brick powder and biomass fly ash, instead of natural raw materials for partially or completely replacing cement paste. Reusing these wastes for the intended purpose solves not only direct environmental problems related to landfill use, but also contributes to lowering energy consumption and CO2 emissions related to the production of Portland cement from natural raw materials and possibly transport. Energy consumption, carbon footprint, recycling, circular ecomonics, life cycle assessement (LCA) and sustainability are important concepts in this context. Although it is clear that problems of mankind cannot be solved in one thesis, the research work done by the candidate during the last few years is without doubt a step into the right direction.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Method of solution

Comments: As far as the five selected papers are concerned, which seem to be representative of the candidate's current research (published 2018-2022), the following can be briefly said:

Paper no. 1 (2021) concerns the (partial) replacement of (Portland) cement by SCMs, in particular the use of biomass fly ash (BFA) as an alternative to coal fly ash (CFA) for this purpose. It is made clear to the reader that the replacement of CFA is necessary because of the planned abatement of coal combustion power plants (due to the increasing use of alternative energy sources and stricter environmental regulations) and the ensuing limited availability of this material. Based on a complex characterization of phase composition, microstructure and mechanical properties it is concluded that materials with BFA as SCM are suitable for replacing cement up to 30 wt.%, while leading to comparable or even better mechanical properties (strength). Moreover, the use of BFA instead of CFA has an additional benefit coming from the lower content of heavy metals in BFA (compared to CFA) and enabling its use in blended cements without further processing.

Paper no. 2 (2018) concerns the (complete) replacement of cement in construction materials by alkali-activated waste brick powder, including the "consequent rationalization of the bulk material streams between the demolition sites and the production of new materials". With respect to the catastrophic destruction situation in the Ukraine, for example, this is a highly timely topic indeed.

Alkali activated aluminosilicate (AAA) materials are prepared with physical parameters and mechanical properties comparable to cement-based materials, while these materials can provide 45 % savings in consumed energy and 72 % in greenhouse gases (compared to Portland cement).

Paper no. 3 (2020) compares different recycling scenarios for waste bricks disposal and comes to the conclusion that cement replacement and alkali activation is usually better than natural aggregate replacement (and landfill). However, the candidate does not ignore the negative effects of alkaline activators on human health and the fact that also from the environmental viewpoint alkali activation is somewhat controversial, especially from the viewpoint of circular ecomonics and ecology when the alkali activators (e.g. sodium hydroxide or sodium silicate) have to be specifically produced by the chemical industry, which again consumes energy and produces waste (apart from the necessity to produce neutralization agents). Therefore the candidate recommends avoiding a one-sided view and concludes that brick waste can be considered as "a viable solution only if a complex technological and environmental characterization is done".

Paper no. 4 (2022) provides a partial solution to the aforementioned problem by proposing the use of waste solidified alkalis (WSAs), here from the glass industry, as an additive to ground granulated blast furnace slag.

Last but not least, and very consistently within this thesis, paper no. 5 (2022) hints at the problem of limited interdisciplinary knopwledge transfer as a missing link for sustainable building materials design. This is an extensive review or opinion paper (with 5 print pages of references) that concerns aspects that go far beyond the field of materials science proper and – apart from technical feasibility – touch problems of environmental protection, economic viability and social acceptance. This paper shows that the candidate has not only deep knowledge in his own field, but also broad knowledge concerning different aspects around this field. I would certainly agree that – due to the immediate social impact on human health, safety and welfare – the "Development and assessment of sustainable cement- and geopolymer composites" is indeed a field that requires much more than just narrow knowledge in materials science and technology.

All five papers are accompanied by short summaries and brief passages emphasizing the practical impact of the paper's results. These comprehensive papers testify the candidate's systematic and consistent work in the field. I highly appreciate this approach.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Quality and correctness of results achieved

Comments: From my point of view the results presented in this habilitation thesis are correct and of excellent quality. But most of all, I appreciate that the candidate's and his co-authors' general standpoint is a critical one and not a naive one. I appreciate that they emphasize the importance of a complex overall view of the total circle instead of a one-sided view of a single segment.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Originality of results achieved

Comments: The general idea and concept of the research presented in this thesis is not new and most of the results are obtained by standard methods that are commonly used in the inorganic binder community, but the results of this habilitation thesis have been obtained on specifically chosen and prepared materials and in this sense they are of course completely original.

Superior	Good	Average	Poor	Not applicable
☐	☒	☐	☐	☐

Publication rate of results achieved

Comments: Ing. Jan Fořt, Ph.D. has an impressive publication record, with 52 papers on the Web-of-Science, in 29 of which he is a first author. Many of these papers have been published in impacted journals. With this publication record the candidate has proven that he is able to develop research in this field on an internationally competitive level.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Response to results and citation rate

Comments: H-index 13, with 474 citations (435 of which non-auto) and 9.12 average citations per item. For a young researcher / scientist this is an excellent score.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Applicability of results to development in the field and for further research

Comments: The approach and methodology applied in the selected papers is not fundamentally new, but is very timely and topical and can be used in a systematic way to many other cement-replacing materials. The thesis thus opens the gate for a broad stream of further research.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Applicability of results to technical practice

Comments: As mentioned above, all five papers are accompanied by brief passages emphasizing the practical impact of the paper's results. Although most of the candidate's papers propose new material design aspects, the candidate does not naively recommend any of them without reservation, but instead he presents a critical view on the pros and cons of a specifc material design solution. This is very wise. And this all that should be required from scientific work. This is what distinguishes scientific work from industrials R&D.

Superior	Good	Average	Poor	Not applicable
☒	☐	☐	☐	☐

Compliance with requirements on thesis – quality of thesis

Comments:

The habilitation thesis itself is structured as a collection of 5 selected papers (11+12+11+14+16 = 64 print pages), with Jan Fořt as the first author, that is preceded by a general Introduction (Section 1, 2.5 pages) and a survey of recent studies concerning sustainable concrete and geopolymer production (Section 2, 21.5 papes), in which the candidate explains the replacement of natural aggregates (incl. 1 table), the partial replacement of Portland cement by supplementary cementicious materials / SCMs (incl. 2 tables) and the replacement of cement composites by alkali-activated materials (incl. 1 table). After the detailed presentation of the 5 selected papers (Section 3) the thesis is then concluded by a short section with Conclusions and directions of future research (Section 4, 2 pages). Both the selected papers and the thesis itself are extremely rich in references (e.g. in the thesis 20 pages of references), which testifies that the candidate is well aware of current research in this field worldwide.

The thesis is written in correct English on an adequate stylistic level.

Superior	Good	Average	Poor	Not applicable
☐	☒	☐	☐	☐

Comments

Overall evaluation of thesis
With this habilitation thesis the candidate, ing. Jan Fořt, Ph.D., has proven not only his deep understanding of all important aspects of cements and geopolymers, but also his broad awareness of ecomonic and ecological (incl. health) problems as well as social aspects related to this topic. Thus this habilitation thesis is a convincing document that testifies the candidate's ability to perform relevant experimental research with a significant economic, ecological and social impact and internationally competitive publication outputs. All this is underpinned by a very solid knowledge of the current literature in the field, as proven by the references cited both in the papers and in the thesis. Therefore my overall rating of the thesis is excellent. Additional comments on the thesis and the author: I would be quite curious to know the candidate's opinion about three general aspects that are somewhat related to the topic of his thesis: 1. Is there any estimate concerning the amount of inorganic binders, energy consumption and carbon dioxide emissions that will be necessary to reconstruct the Ukraine? Is there any approximate relation of this to the raw materials savings, energy savings and CO2 emission reduction that can be achieved by worldwide research and development as in this thesis. 2. The recent earthquake in Turkey has shown the necessity to use suitable building materials (and construction principles) that may be specific for the region and its geological (and climatic) situation. Are building materials based on non-Portland-cement expected to be suitable also for earthquake regions (seismically active regions)? 3. In his experimental work the candidate applies many of the characterization techniques that are commonly used in the inorganic binder community, including measurements of mechanical properties such as compressive and bending strength after 28 and 180 days, for example, which are of course of primary importance from the viewpoint of common use. Elastic properties are much less frequently measured in this community, although they are equally easily measured and nicely reflect the actual state and the temporal evolution of phase compositon and microstructure as well. What is the candidate's opinion about the use of elastic measurements, e.g. by the impulse excitation technique (IET), in the field of inorganic binder materials in general? Should elastic properties be inlcuded in future international quality standards for inorganic binder materials or is their significance too marginal for that?

Promotion to associate professorship recommended	*yes* ☒	*no* ☐

Date: 6.3.2023

Reviewer's signature: [redacted]