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Review of the doctoral dissertation entitled "Prediction of the mechanical and electrical properties of cementitious composites using artificial neural networks" by mgr inż. Sofiji Kekez

1. Formal basis for the preparation of the review

The formal basis for the preparation of the review is a letter from the Chairman of the Civil Engineering and Transport Discipline Council, dr hab. Eng. Marcin Staniek, professor of the Silesian University of Technology (l.dz. RDIT / 512.10.2022) of 08.07.2022 informing about the resolution of the Discipline Council entrusting me with the duties of the reviewer and the preparation of the opinion of the doctoral dissertation as formulated above. The dissertation is presented in English, however I was informed that the review should be prepared in Polish.

2. Subject of the review

The subject of the review is the study entitled "Prediction of the mechanical and electrical properties of cementitious composites using artificial neural networks" by mgr inż. Sofiji Kekez, presented to the Discipline Council of Civil Engineering and Transport of the Silesian University of Technology as a doctoral dissertation. The thesis supervisor is prof. dr hab. Eng. Jan Kubica, and the auxiliary supervisor - dr inż. Marcin Górski. The author of the dissertation, mgr inż. Sofija Kekez is a graduate of the Interdisciplinary Doctoral School of the Silesian University of Technology "Simulation in Engineering" (2018-2022). Professional title of master's degree in civil engineering in the specialty Engineering structures (2015-2017) obtained from the University of Novi Sad, Serbia, and in 2015 she obtained a bachelor's degree at the University of Novi Sad. The doctoral student is the author or co-author of 14 publications, a member of RILEM, she actively participated in nine scientific conferences in various European countries.

MSc. Sofija Kekez presented her doctoral dissertation of 165 typescript pages, including 65, often very complex drawings and 28 tables. Two appendices were attached to the dissertation: A - ANSYS simulations (30 pages), which presents the tabulated results and their illustrations presented in 16 figures; B - Artificial Neural Network (106 pages), in which the results are tabulated on 45 pages, and the remaining pages are devoted to the presentation of these results in the form of regression functions and histograms.

The content of the dissertation is presented in nine chapters. In the Introduction, the reasons for taking up this subject are presented, and then a literature review on the design of concrete (II.1) and artificial neural networks (II.2) is presented. Chapter III, distinguished as Theoretical background, presents the basic concepts and relationships concerning electrical engineering (III.1), concrete design (III.2), self-sensing concrete (III.3), numerical simulations (III.4) and artificial neural networks (III.5). Then, research hypotheses were presented (IV). Chapter V is the research part - Experimental research, which presents: materials (V.1), the method of sample preparation (V.2), research methods (V.3) and standards (V.4). Based on the obtained results - "based on the results of the experimetal research" - numerical analysis and appropriate simulations were presented (VI) and a model of artificial neural networks (VII) was developed, which was tested and the results validated. Conclusions are presented in Chapter VIII, and valuable indications for further research in Chapter IX. 134 literature items were cited in the dissertation, including two co-authored items by the PhD student published in Materials (IF = 3.6). Along with the original of the dissertation, a nine-page summary of the thesis in Polish was made available.

3. Assessment of the purposefulness of taking up the topic and the accuracy of the formulation of the scientific problem and research theses

The subject of the work is one of the important, developing directions of research, important for the technology of concrete and, consequently, for the creation of the material achievements of civilization.

The search for scientific tools to improve the design of concrete is particularly important now, when the use of nanomaterials creates a situation that a small proportion of the component causes significant changes in technical properties. The title of the dissertation in the Polish language version begins with the words "Prognosing". The use of the verbal noun "forecasting" in the title definitely indicates the process, and not its result - "forecast". Perhaps "prediciting" would be more accurate in English. The justification provided by the author (II.1) almost entirely refers to the methods of designing a concrete mix. The question is whether it would not be more accurate to show it in the title of the dissertation, eg "Concrete design method using an artificial neural network".

Eight research hypotheses were formulated in the dissertation (III, p. 60). These hypotheses were formulated in very general terms, both in terms of sets: mechanical properties and electrical properties of concrete, and the activities they concern: "improves, models, realistically corresponds, forecasts, predicts". The set of mechanical properties is much more numerous than those mentioned in the dissertation; e.g. features related to the phenomenon of creep have been omitted. Also the phrase "enhanced electrical properties" raises doubts due to

its general nature - will it mean, for example, increased "conductivity" or increased "resistivity".

Considering the set of hypotheses in terms of "originality - obviousness", it can be seen that many of them, in the light of the current state of knowledge, are close to obvious - especially it concerns the improvement of the mechanical properties of concrete by the addition of CNT or CNF. Regarding the use of ANSYS MD, the dissertation "determines the feasibility of ANSYS" rather than answering the question "can be modeled by ANSYS?" This position is adopted by the author in the publication "Numerical simulations of CNT / CNF reinforced concrete using ANSYS" [W: Rossi, P., Tailhan, JL. (eds) Numerical Modeling Strategies for Sustainable Concrete Structures. SSCS 2022. RILEM Bookseries, vol 38. Springer, Cham. https://doi.org/10.1007/978-3-031-07746-3_18], which appeared after the preparation of the doctoral monograph (see also Roopa A.K., Anand M. Huanshyal: Evaluating Self-sensing Property of Carbon Fiber Cement Composite by experimental study and Finite Element Modeling For Structural Health Monitoring Applications, In: 2021 IOP Conf. Ser .: Mater. Sci. Eng. 1070 012041; not quoted in the dissertation).

The scientific problem, the original solution of which is legally required, has not been directly defined in the paper. However, I believe that in the set of hypotheses under consideration it is possible to find the formulation of a scientific problem, however, it should be reduced the number of hypotheses and make it more specific. In the present approach, the formulation of the scientific problem may be treated as implicit.

4. Assessment of the correctness of scientific inference

The aim of the work - by its very nature - was to prove the research hypotheses that were presented in the dissertation (chapter IV). Indeed, all the reasoning presented in the paper is consistently subordinated to the realization of this goal. The Introduction (p. 12) presents "the objectives of this dissertation", including:

- "Forming a comprehensive collection of experiments done on CNT / CNF reinforced concrete, including all possible factors which would affect the final performance of the composite material";
- "The introduction of self-sensing cementitious materials into everyday civil engineering practice";
- "Establish a possible alternative to traditional concrete mix design methods".

This compilation can be treated as partial goals that were implemented along with the proving of hypotheses. The greatest doubts are whether alternative methods of concrete design have been established. We should agree here with the author's statement, quoted at the end of the Polish summary, that it was the idea of this work, however, its full implementation requires

further work, the outline of which is included in the chapter Directions for further research (IX).

The second important general remark concerning the scientific problem was presented in the previous point of the review. The following comments are point-based:

- the criteria for selecting CNT and CNF nano-additives as appropriate for achieving the objectives of the work were not mentioned;
- "Artificial neural network models are based on data, excluding the need for specifying the underlying mechanism of the problem." (p. 19). Is this statement too categorical or will it not lead to a "false-relationship"?
- "the quality of the binding is dependent on the relationship between the cement paste and the type, shape, and size of the aggregate". "Aggregate surface" was omitted;
- "higher permeability of concrete" is treated as "improvement" (p. 28). This may only be right for concretes in some applications. Whereas compressive strength decreases with the pore content in the sixth power, this does not apply to structural concretes;
- among the 11 methods of concrete design mentioned (p. 29), the method according to the European standard EN206 was completely omitted;
- "the ability of sensing [...] damage and simultaneously improving its mechanical properties" (p. 31). The requirement to improve the mechanical properties simultaneously with the destruction of the "damage" seems to be a redundant expectation, it would be a post factum action. Here and in the following sentences, we should think of "damage thread" rather than "damage";
- the given dimensions of samples (p. 70), except for the 150 × 150 × 150 cube, may only be used for mortars, due to the relationship "maximum size of aggregate grain - minimum size of the form";
- in the context of the results (p. 80) for cem 52 504 NT05 the value: Young's modulus 231.44 GPa exceeds more than five times the reference value for C90 / 100 according to Eurocode 2.

Despite the imperfections noticed, I believe that the work proves a satisfactory mastery of the scientific technique. By analyzing the existing state of knowledge, a sufficient general orientation was demonstrated, and the analysis itself was thoroughly conducted and presented in a condensed, structured form (eg Tables 5.2 and 5.3). For example, "honest" presentation of the limitations resulting from the use of ANSYS (p. 59) or the statement (p. 52) "these are only recommendations and cannot be dogmatically followed", or a very accurate statement (p. 128) "All models show reliability of over 0.99, however, it only implies that the prediction, which the network can provide, matches the simulations and not a realistic situation. ", as well as noticing (p. 131) the possibility of " a false-positive result "- this is a good recommendation of the values of the future scientist.

5. Assessment of the scientific editorial staff

The layout of the work is typical for experimental work and it is also impressive. The subject of the research is cement concrete modified with carbon nanotubes, CNT, and nanofibers, CNF. A special feature of this dissertation, however, is the fact that the subject of research remains "virtual" in the sense that this work did not produce a single result of one's own experimental measurement. All initial experimental data remained collected on the basis of the analysis of 35 literature items (84-119) and allowed the creation of a valuable "Material Library" - "Materials Library" (table A 1.1). Direct information about the procedure adopted in this way should appear in the introductory chapter I.3 Methodology of research . One of the main conclusions from the work - although not articulated, but extremely inspiring - should be that in the science of concrete we do not suffer from a deficit of data, but from a lack of ordering and proper elaboration / interpretation. Appendices A and B constitute convincing evidence, where, among others, nearly 1000 values of material properties were generated for the simulated samples.

In several workplaces (e.g. pp. 61, 89), there is a suggestion ("the actual capabilities of concrete as the insulating matrix") that the research concerns insulating concrete. This could explain why the high permeability of concrete is one of the advantages. The whole dissertation, however, concerns, at least by default, ordinary concrete - "Ordinary Cement Concrete", i.e. structural concrete. It is a pity that this circumstance was not unequivocally resolved.

The following are other remarks regarding the scientific editing, in the order as they arose during the study of the work:

- the "keywords" list is missing;
- in the dissertation, the term "materials" is commonly used to mean "concrete-making materials" (S. Popovics, 1979; not quoted) - it is a very general category. In the context under consideration, often "ingredients" would suffice as constituents of concrete;
- Fig. 3.3.2 listed on p. 38 does not correspond to Fig. 3.3.2 on page 33; the correct drawing has probably been omitted;
- the list of symbols, although extensive, is incomplete; e.g. the C-S-H phase was omitted (p. 40);
- Fig. 3.3.4 (p. 42) is missing the marking of the vertical axis;
- K^{2+}, Na^{2+} (p. 43) - there are no such ions;
- for the sake of order, it should be noted that according to the European standard EN197, Portland cement is marked as CEM I, CEM II etc. (p. 61 and following, eg table 6.1);

- "Strength classes of the used OPC are 42.5 and 52.5, meaning that [...] is 42.5 MPa and 52.5 MPa" (p. 61). Should be: above 42.5 MPa and above 52.5 MPa;
- "the ratio of 1 / 0.4 for cement / water" (p. 79). It should be: 1/4;
- Fig. 6.5.1 - 6.5.5 - Undescribed horizontal axis.

At the end, the author cited a bibliography of 154 correctly - as it may be assumed - selected references of over 300 authors. I note with admiration and humility that I have not associated the great majority of these names with the science of concrete so far. Among such a large collection, there is only one reference to Polish works - this is an article by the auxiliary supervisor: M. Górski et al. [61]. There were no other works from the diploma university, as well as, for example, Z. Waszczyszyn: Artificial neural networks in civil engineering: another five years of research in Poland. CAMES, 2011, 18 (3): 131-146. I do not claim that taking these references into account would change the significance of the author's arguments, but I am asking for some academic courtesy.

6. Summary and final conclusion

Despite the imperfections noticed, I evaluate the submitted doctoral dissertation positively and I believe that the doctoral monograph is an important item in the search for the development of the science of concrete.

Pursuant to the Act of March 14, 2003, the doctoral dissertation should be an original solution to a scientific problem, demonstrate the general theoretical knowledge of the candidate, as well as the ability to conduct scientific work - I conclude that all these conditions in relation to the dissertation of MSc. Sofiji Kekez were fulfilled.

Tłumaczył prof. Jan Kubica