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Review of the Doctoral Thesis of Ing. Zakaraya Alhasan on
„The probabilistic solution of dike breaching due to overtopping".

According to the mandate of the Dean of the Faculty of Civil Engineering, Brno University of Technology I will try properly to review results of the research activities of the PhD student of the Institute of Water Structures Ing. Zakaraya Alhasan.
His research activities were concentrated on reliability analysis of flood protection dikes by estimating the probability of dike breaching due to overtopping.

1. *Actuality of the chosen topic of the doctoral thesis*

Failures of dikes or dams is a topic (whatever is the reason for it) which is all the time very actual because of the length of dikes along rivers all over the world. There are thousands of kilometres of dikes and each failure can cause a serious problem for the environment and the humankind itself. This topic has been elaborated in many research studies theoretically, in laboratory as well as in field conditions, but a real theoretical solution still has not been achieved yet. Therefore, the reliability analysis of flood protection measures has to be appreciated as an actual topic of the doctoral thesis of the PhD student Ing. Alhasan.

2. *Selected methods of the elaboration of the thesis and obtained results*

The whole thesis and its results are based on a very comprehensive review of the present state of research in the mentioned field. This review creates the majority of the thesis. Ing. Alhasan is presenting - after introducing the terminology of the problem solution - several scientific studies as well as laboratory and field experiments focused on analytical and mathematical modelling of dam breaching process. Results obtained from failures of real dams from all over the world as well as from Czech Republic are presented here. Next review is dedicated to statistical research studies mostly presented in extensive database of historical floods in Czech Republic (Morava or Odra river basins).

Chapter 4 is dedicated to explanation of basic definitions and parameters of the temporal development of dike breaching. These parameters are clearly described in the chapter and illustrated in Fig.4.1 and 4.2. According to number of individual failure modes, the failure of dikes due to overtopping is significantly the most frequent reason for the failure of dikes in mentioned two river basins in Czech Republic. Therefore, I agree, the dike reliability from the point of view of dike failure due to overtopping is the most important problem.

The PhD student Alhasan furthermore explains in his thesis the dike breaching development. He defines three hydraulic zones coming from subcritical flow regime in the former river bed to supercritical flow regime on the downstream slope of the dike. The flow accelerates to reach high values of flow velocity and connected shear stress to initiate erosion of the material of the dike which can accelerates very rapidly.

With the dike overtopping the problem of slope surface resistance occurs, as well. Mostly the relation between critical shear stress and non-scouring velocity was used to define the scour resistance of dike material in case of non-fortified slopes. There are several authors mentioned for empirical expression of critical shear stress according to different parameters like density (water, sediment), effective grain size or other. Although, the references are mentioned in the thesis, I would appreciate to show them at the defence to see the differences among them and the development of the research in this field of study. A more detailed comparison between solution of expression of critical shear stress of unlined and lined surfaces (slopes) is recommended.

3. *Solution procedure of the problem and results evaluation*

The progress of the dike breaching due to overtopping is clearly shown in Fig.6.3 – Fig. 6.7. The dike is collapsed due to backward erosion of the upstream slope - that is clear! What about lateral widening – can it be somehow theoretically described and determined? The Fig.1 is showing us possible event scenarios where the related parameters are clearly presented. Just I am missing one more parameter and that is the duration (time) of the overtopping which can be seen on the right side of the figure. What is the opinion about this fact of the Phd student? In the thesis qualitative as well as quantitative analysis is presented.

The most important part of the thesis is the reliability analysis methods of which have been developed gradually. I agree with assumption that the flow downstream the slope is quasi-steady and uniform and that the process of dam breaching consists of two parts – overtopping and possible erosion. The author has divided the mathematical model of the process in two modules: hydraulic and erosion module. The hydraulic module is presented to be overflow

through broad crest (Eq.8.2). What I do not understand is the Eq.8.3 coming from Chezy's formula. Can you advice me and show at the defence how did you receive this equation? The erosion module is presented as an instantaneous change of elevation of the breaching opening bottom as well as instantaneous change of breach opening width. Those changes are given by Eq.8.6 and 8.7 and relevant coefficients are empirical. Tab.8.1 is presenting values of α_1 coefficient derived from real dam breaches. Can you provide me with one example of establishing this coefficient? Are they not too empirical? What is h_d in the Tab.8.1. It is nowhere explained. I suppose this is the height of the dam crest, isn't it?

For the estimation of the probability of dike breaching a modification of the Monte Carlo (MC) method called Latin square sampling (LHS) has been used. The author presents the advantage of the LHS comparing with MC method.

Two remarks to the modelling:

- Equation 7.6 does not exist (page 44),
- Triangular schematization of the flood wave (Podhradí gauging station) is to my opinion overestimated. What is the opinion of the author? Which flood wave happened in the summer and which in the spring time (blue or red coloured)?

The proposed computational procedure was used to study an endangered location on the Dyje River close to Ladná village (fig. 10.1). The definition of flood wave parameters (duration, peak discharge, shape) has been evaluated according to ČHMÚ data. Required reference values of input parameters are given in Tab.10.2. Although the parameters are clear I have some doubts about the certainty and reliability of those parameters and especially of their determination. Results of the sensitivity analysis are the result of parameters summarized in App.1. I would appreciate more detailed explanation to Fig.10.4.

Final results evaluation consists of determination of typical phases mentioned above for different lining material. Maybe the most important result is the comparison for "no overtopping" phase with the "accurate" result obtained from Eq.10.1. A logical conclusion is presented according to results in Fig.11.2, i.e. decrease of probability of dike collapse with the increase of resistance of the lining material.

4. *Significance for the practice and progress of the field study*

Thesis is dealing with a very serious problem – dike reliability solved by probabilistic assessment. It is a good attempt to deal with so many uncertain parameters which appear when solving this problem. It is a progress in the given field of study and I agree with the author to use more dimensional models. The question appears: are there any other important parameters

which have to be taken into account when solving the dike breaching due to overtopping by stochastic methods? What is your opinion?

5. ***Formal layout of the PhD thesis and its linguistic level***

Formal layout of the PhD thesis of Zakaraya Alhasan is well constructed and graphical presentation of results is on good level. I have mentioned some additional equations which could accomplish the text of thesis. I have found some grammatical mistakes which are really negligible and do not influence the quality of the thesis.

Conclusion

I recommend the PhD thesis of Zakaraya Alhasan to defend it and after a successful defence to award the PhD candidate Zakaraya Alhasan the scientific title PhD.

In Bratislava, 25.4.2017