Optimal numerical models selection for flood embankment pore pressure data

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Introduction

One of the greatest natural hazards occurring in our country are floods. In order to understand the mechanism of formation of the floods in the river bed and evaluation of the stability of flood embankment, research within the project ISMOP are carried out.

The aim of this project is to study processes occurring in the earthen flood embankments under the changes in water level in river bed: water filtration, changes in pore pressure and temperature in the embankment. The main goal of ISMOP project is to develop a system of continuous monitoring of flood embankment stability. Real-size earthen flood embankment with built-in sensors was built in Czernichow. While conducting various experiments, the parameters are measured with a time step of 15 minutes.

Fig.1. Experimental flood embankment (fot. M. Dwornik)

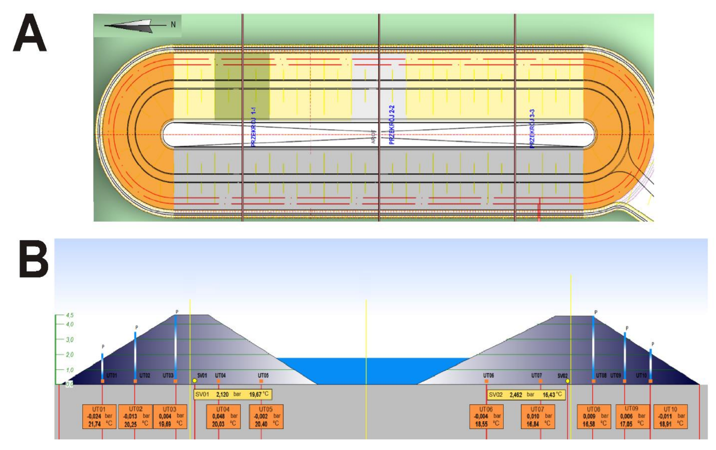

Fig. 2. Scheme of the flood embankment.
Source: Zieliński & Chrost, 2015

Numerical modelling

Numerical modeling was performed using Itasca Flac 2D 7.0 software. This software used finite-difference method to simulate water filtration or heat transfer in geological medium.

In this case, squared grid size model was used. The size of model is 92.4x7.5m (924x75 cells) with 20m horizontal offset and 3m of depth. Value of geomechanical parameters was presented in table 1. Air temperature and water level inside reservoir was updated with 1h steps. These parameters and initial water saturation inside levee was obtained from measurements recorded during real experiment, (fig.3).

Table1. Geomechanical parameters
Source: Borecka et al

	Symmetric levee	Asymmetric levee	Subsurface	Silty	Sand
Density [g/cm3]	1.90	1.96	2.10	1.89	1.85
Cohesion [kPa]	12.50	15.43	10.30	13.70	10.00
Friction [deg]	30.04	35.20	32.90	22.50	36.20
Bulk module [MPa]	8.53	7.25	7.25	16.20	36.30
Shear module [MPa]	3.27	3.35	3.43	6.63	21.80
Porosity	37%	27%	27%	40%	35%
Infiltration factor [m/s]	1.83 $x10^{-4}$	5.24 $x10^{-4}$	1.52 $x10^{-4}$	1.35 $x10^{-4}$	5.60 $x10^{-5}$

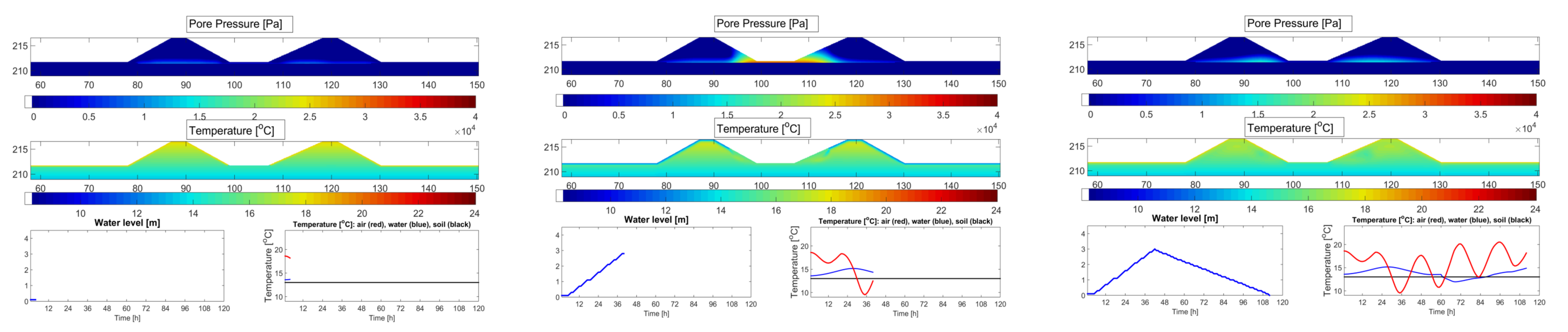

Fig.3. Numerical modelling at time stamps: 14400, 144000 and 403200 s

Model-driven module

Numerical modelling and information about phenomena inside the embankment due to external factors and changes in the riverbed can be used to assess the state of a flood embankment. The purpose of model-driven module is to perform a comparison of the actual measured parameters from the sensors with the numerical models. The analysis for each half-section of the flood embankment is carried out separately.The general scheme of real data comparision from experimental flood embankment with numerical models is shown in the figure 4.

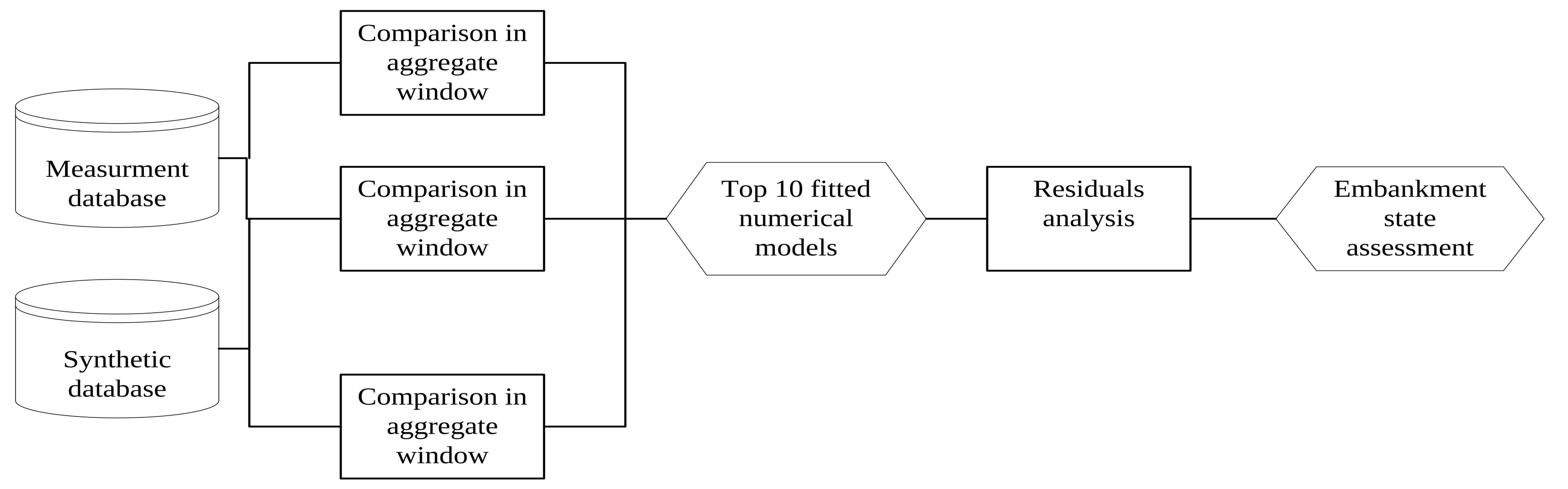

Fig.4. Model- driven module scheme

A time series is collected from all numerical models from the Synthetic Database for nodes corresponding to the position of chosen sensors (from the half section). The Mean Square Error (MSE) is calculated in an aggregate window of 100 observations for each numerical modelling. Among the calculated values of MSE, the highest value with the amount of offset for the numerical modelling is recorded. For each sensor in the half section, the 10 best numerical models are selected with the smallest MSE values that suit the comparable time series from the half section based on the MSE. In subsequent iterations of the model-driven module, the length of time series from sensors increases by 1 each time. Until MSE rises above the critical value, comparison occurs only between the pre-selected 10 best-fit numerical models.

For the 10 best-fit numerical models, the differences (residuals) between this data and the time series from sensors are computed. The values and variances of the residuals are checked for increases in time that exceed the critical value designated in tests. If a model matches the first part of data but the similarity subsequently decreases, a phenomenon has probably affected the value observations.

Tests

For the tests, NW half section was chosen, which includes sensors UT6 to UT10 (Fig.5). UT sensors measure temperature and pore pressure at the same time. Selection of the best numerical modeling was carried out for the actual data recorded by the sensors during the experiment, which was the raising of water level in the flood embankment to a height of 3m. The experiment lasted from 08.29.2016 hour 9 pm to 03.09. 2016 hour 9am.

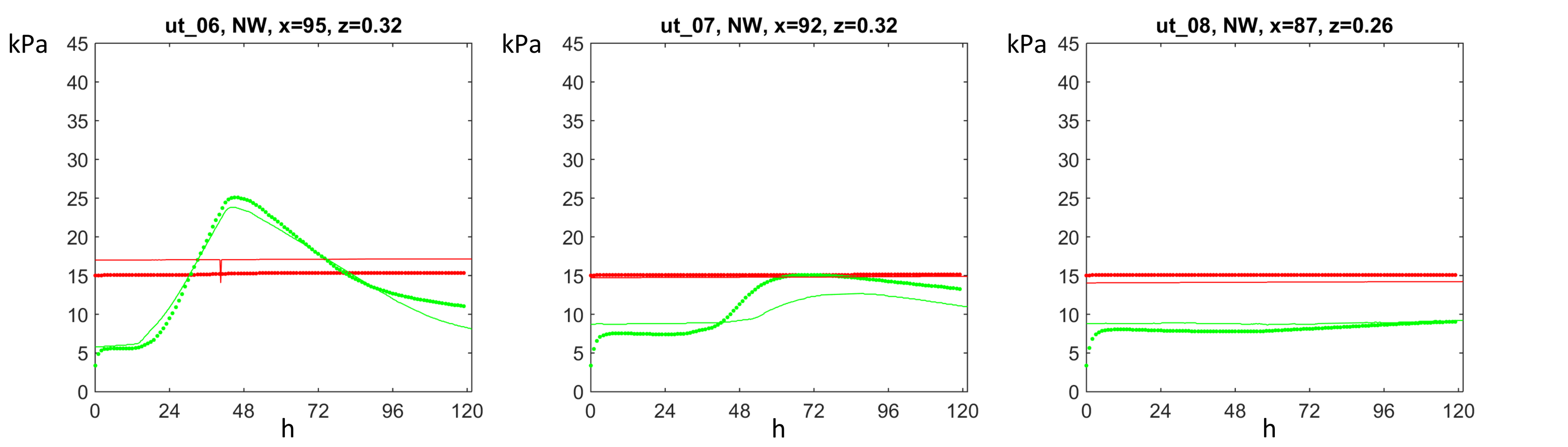

Fig.6. Comparison of numerical model 1 and real data for sensors UT6-UT8

Performed test includes comparison of three numerical models with real data from experiment of water column raising to 3 meters from NW half section, with diffrent initial parameters. In the first step using a Mean Square Error (MSE), a comparison of the experimental data with both numerical models is conducted. Dissimilarity metric (MSE) for numerical modeling 1 (Fig.6) range from 212 for UT8 to 259 for UT6 sensor, which is consistent with the graphic representation (Fig.6.). For the numerical modelling 2, the MSE exceed 300, for numerical modelling 3, the smallest value of MSE exceed 350.

Conclusions

The chosen method allowed to select an appropriate numerical model for the experiment conducted on a flood embankment. The most important problem to be solved is to find the suitable critical values for the selected algorithms. The biggest differences in the analyzed data are related to temperature. In further tests, the analysis of its impact on the algorithm's results should be performed. What is more, the assessment whether better results could be obtained for the temperature gradients should be done.

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Acknowledgments. This work was partially supported by the National Centre for Research and Development (NCBiR) under Grant No. PBS1/B9/18/2013 and by the AGH grant no. 11.11.140.630.

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