EAN 2017
55th conference on experimental stress analysis

Testing and numerical analysis of mechanical stress mobile flood barriers

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Keywords: flood, barrier, experimental measurement, numerical simulation

Abstract. This paper deals with experimental testing and numerical simulating of flood barriers. Floods are an integral part of the natural water cycle and can cause great loss of life and great property damage. The Czech Republic has been hit by several very devastating floods in past years. The development of new types of flood barriers is very important. The currently developed mobile barrier is characterized by its easy assembly on different surfaces. During the development of the mobile barrier several experiments have to be carried out. Based on the results from these experiments numerical simulations were created using Abaqus software. The results of simulations show good agreement with the experiment. These numerical simulations will be used as an effective replacement for experimental tests, which will lead to shorter development times and lower costs.

Introduction

Nowadays flood barriers with concrete substructure reliably protect against flood. These barriers are used mainly in the large port cities or cities with large rivers. The issue, however, is the construction of flood barriers in the villages and smaller towns. Inhabitants of small towns and villages do not want barriers with substructure because of landscape distorting, damaging vegetation and complicate agricultural work in the fields. Therefore, sandbags are still used for flood protection and removed again after finishing danger. Development of flood systems leads to the mobile flood barriers which can be quickly installed and uninstalled after the flood. Constructional prototypes of these barriers must be tested in test channel at the different heights of water level, against log impact [1, 2] also for different types of terrain. These new barriers must be low maintenance and storage demands.

Experimental measurement

The mobile barriers are tested in real flood conditions with floating log. Several measurements were carried out where the aim was to achieve statistically significant values. Therefore the type 1 measurements (artificial test channel) Fig.1 (left) were carried out first, for required water velocities from 1 to 4 ms^{-1} with a step of 0.5 ms^{-1} at the moment of impact, as published in [3]. Subsequently the type 2 measurements (river bed) Fig. 1 (right) were carried out. The water was released from reservoir and then went through the test track with a tidal wave. In the type 1 measurement the direction of log movement was defined by its anchorage by pulleys on the guide wire. In the type 2 measurement the direction of movement of the log was not limited; the log movement was given by the water flow.

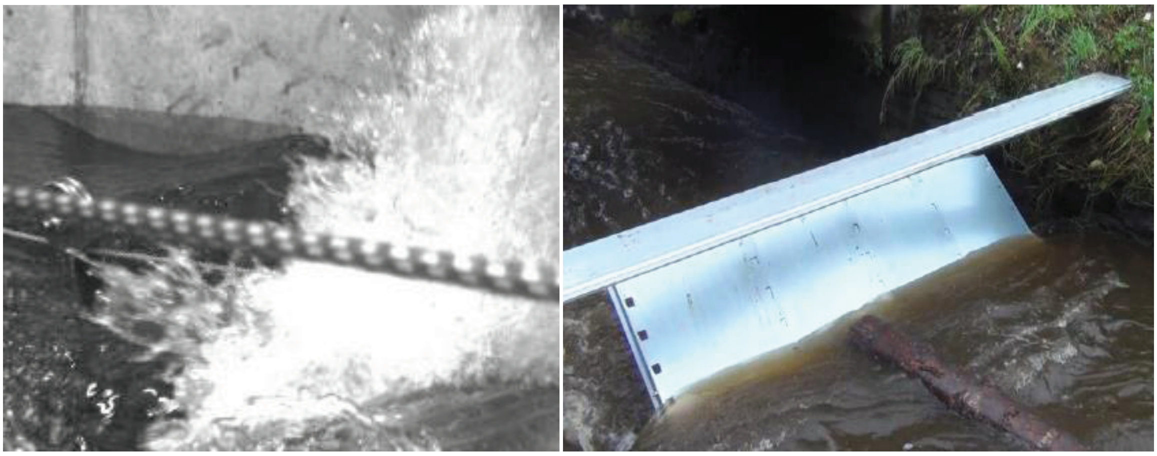

Fig.1 Measurement type 1 (left) [3], measurement type 2 (right)

Used instrumentation:

- 2x contactless laser sensor for measuring barrier movement
- incremental motion sensor for measuring log movement (position + speed)
- uniaxial accelerometer for measuring log acceleration
- 1x high speed video camera at the point of impact of the log into the barrier

The speed of the log movement was calculated in real time as a derivation of the incremental position sensor signal. The barrier and the log was recorded by high speed video camera. Laser sensors measured deformation of the barrier. The layout of experiment of flood system without substructure in real geological conditions is shown in Fig.2

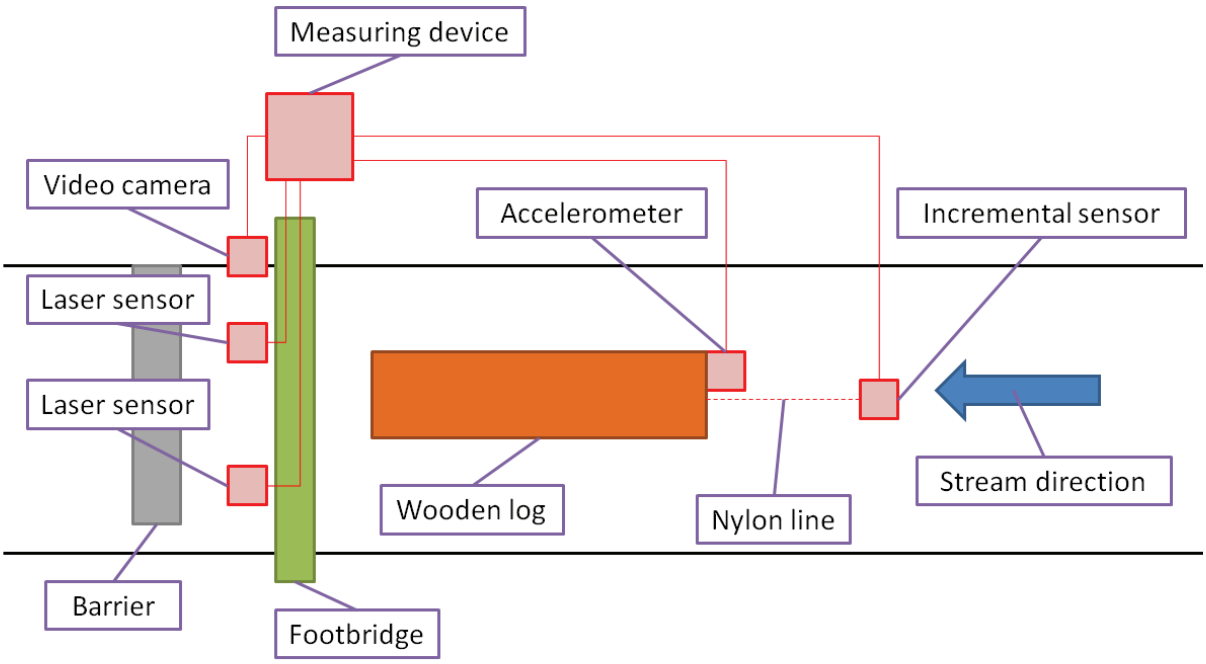

Fig. 2 The layout of experiment.

Numerical modeling

A simplified CAD Fig.3 (left) model of flood barrier, wooden log and water space, was used to define the numerical simulation. For the simulation the barrier was replaced by simple plate of 1.5x1 m. The volume where water can move was created as a block of 7.5x1.5x1.5 m. The initial volume of water was created as block of 5x1.5x0.5 m. A log was created as cylinder with a diameter of 0.2 m and 3 m length with density of 900 kgm^{-3} (weight 85 kg), which corresponds approximately to the log used in real experiment.

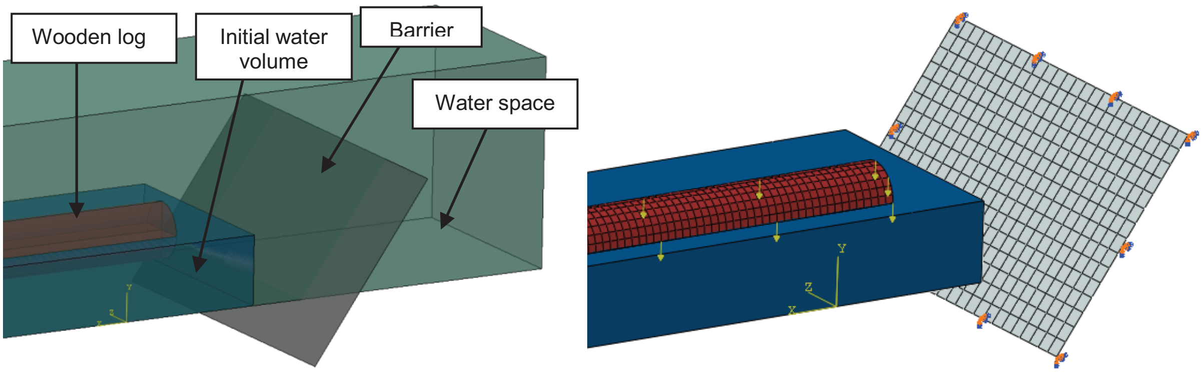

Fig. 3 CAD model of barrier (left), numerical simulation assembly (right).

The mesh used in the simulation was quite coarse. The water volume was meshed by 16,000 brick elements with edge size 0.1 m, the wooden log contains 4,800 brick elements with the shortest edge 0.028 m and the barrier contains 375 shell elements with edge length 0.1 m.

The gravitational acceleration of 9.81 ms^{-2} was applied on the whole assembly. On the barrier were applied fixed constraints at the points corresponding to footholds of real barrier Fig. 3 (right). The initial water velocity was set to match the tidal wave velocity measured in the test channel.

Results

The first simulation was carried out mainly to prove that the FEM method can be used for water modeling in such time and spatial range. From a visual comparison of simulation and the record of high speed camera it can be concluded that both waveforms are very similar Fig.4. Subsequently refined simulations were carried out. Results of these simulations are relatively accurate and are an auxiliary tool in developing new barriers.

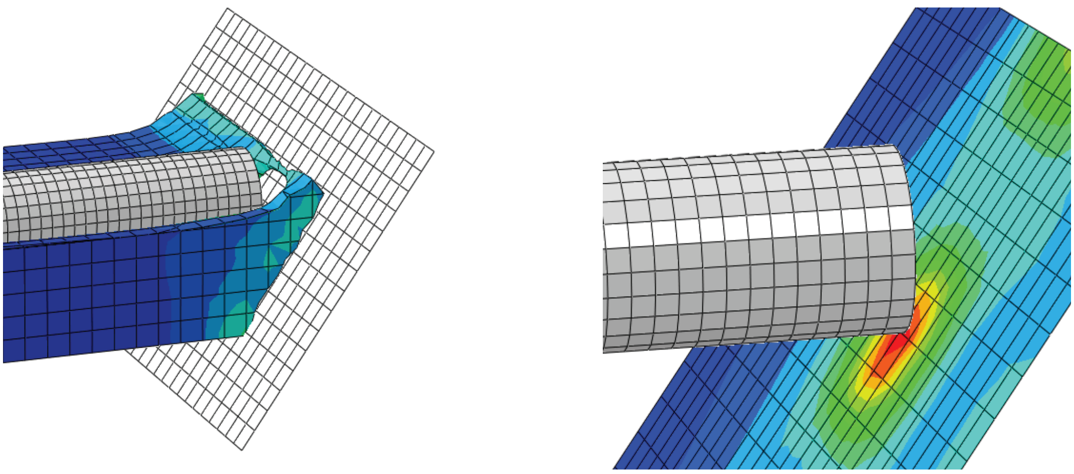

Fig. 4 Results of numerical analysis

Tidal wave speed of 1 ms^{-1} was achieved in a real experiment. At simulation was achieved higher speed of tidal wave, which can be about 3 ms^{-1} during the flood. Fig. 4 shows the course of deformation of the barrier at different tidal wave speed.

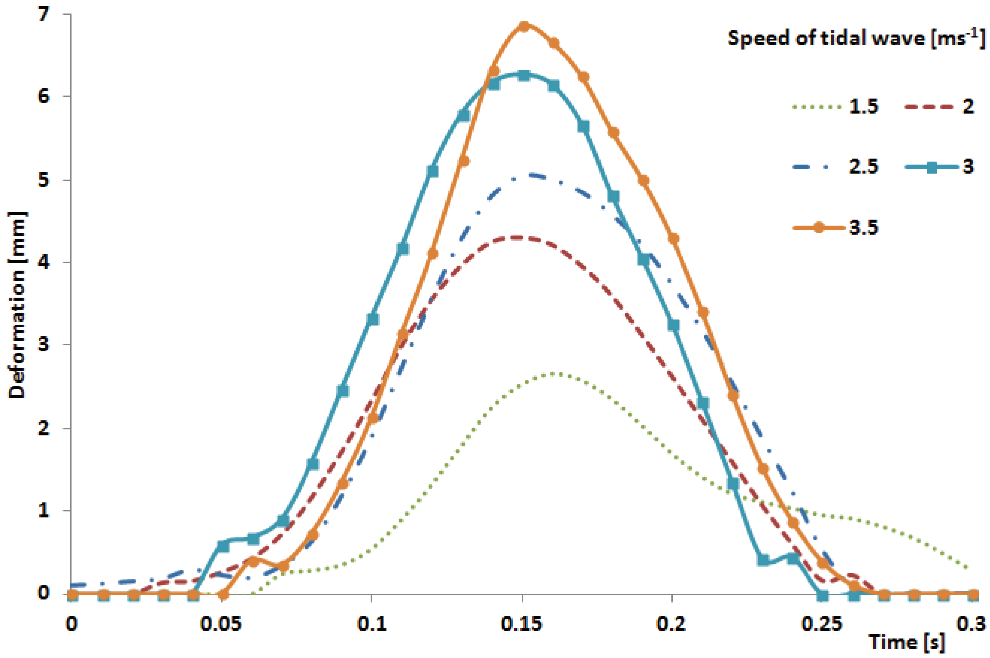

Fig. 5 Deformation of the barrier

Conclusion

In case of a sudden flood, it is necessary to divert water out of the inhabited area as quickly as possible. The solution may be the barriers with substructure, but these are quite expensive. Therefore, use of mobile barriers may be a better solution in some cases. Mobile flood barriers have to meet many requirements, like easy installation, low weight, low price, low storage demands and so on. All these requirements must be considered for development of new design of mobile flood barriers. During the development of barrier many experiments have to be done. FEM and computing capabilities are now at a high enough level to allow numerical simulation of relatively complex phenomena such as fluid and structure interactions. These numerical simulations can successfully replace and complements some of the experimental tests with sufficient accuracy.

Acknowledgements

The results of this project VI20152018005 were obtained with co-funding from the Ministry of the Interior of the Czech republic as part of targeted support from the project "Vývoj protipovodňových systémů pro zvýšení ochrany obyvatelstva a infrastruktury".

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