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4th International Conference on Road and Rail Infrastructure
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Road and Rail Infrastructure IV

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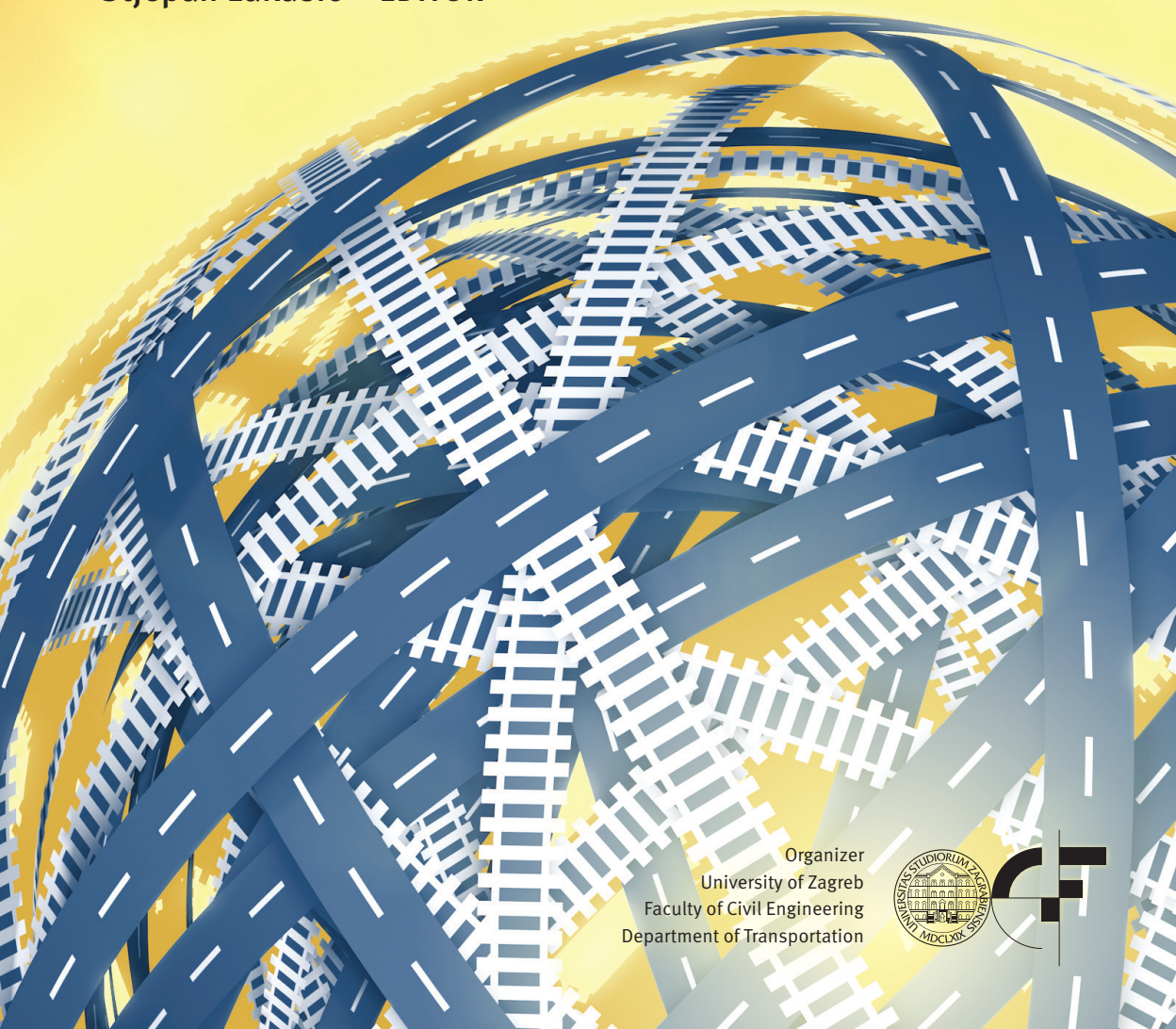

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LEVEES CONDITION ASSESSMENT IN CROATIA

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Abstract

Levees are long linear structures where are often unavailable or insufficient data from the preliminary design to maintenance during exploatation and monitoring. Their importance is in the first place the protection of human life and material and other goods. In Croatian history the levees are almost always built when the need for flood defence or to improve the existing system of protection against adverse effects of water. Such actions are mainly implemented without the required geotechnical investigations, internal regulations and the prescribed monitoring of levees. But levees are not static structures as well as the high water level on which the levees are designed. In the Republic of Croatia in the last ten years extreme hydraulic phenomena are recorded which influenced the levees. Because of such construction conditions and the levee aging there is a need for serious systematization of levees state. Due to the impact, but also the significance of levees it is important to maintain them safe and therefore continue to implement monitoring. In this article monitoring through the assessment of the levees is proposed, whose basic idea is foundation and levee data collection. Negative effects on the levees and indicators that should be monitored and the importance of levee assessment and the guidelines and recommendations for the levee assessment implementation are described. Appropriate geotechnical investigations and monitoring provide the levees assessment and give the timely response due to the information of the possible collapse modes or levee deterioration. The systematic levee monitoring and the data obtained by geotechnical investigations, measurements, and even the very visual observation and the resulting levee assessment provides a great opportunity to use for the purpose of designing, building, construction and new levee exploatation.

Keywords: levee, maintenance, levee condition assessment, monitoring, failures

1 Introduction

The levees in Croatia were constructed without proper geotechnical investigations, standards and monitoring during exploatation but with known and accepted engineering practice. The reason for this practice was the fact that they were built at different times and in different economic circumstances, and almost always for the purpose of the current flood defense or to improve the existing flood protection system. Due to such construction conditions and the now old age there is a need for serious systematization of built hydraulic structures, especially of levees [1].

This paper aims to explain the importance of conducting levee monitoring, respectively the implementation of the new methodology for levee assessment in which indicators are recognized pointing to levee failure mechanism and makes suggestion on the frequency of conducting levee assessments.

As well as levees are ageing as the construction and a need for levee maintenance and remediation is constant, nowadays there are fewer funds for financing. By conducting levees

assessments, the routing of funds is enabled directly to those locations where it is really needed. By regular implementation of the levee assessment first of all the database of levees is created, which means easier monitoring of levees during the designed lifetime and by visual inspection changes are noticed timely. The results of such levee assessments, in the end, serve as a basis for decision-making for maintenance and on time remediation and in addition serves just for better understanding, help in management and reducing the risk of floods related with levees. All these are reasons why it should be considered and to accept new methods of monitoring and levee assessment.
This paper was partly created after a detailed study carried out in the basin area of the City of Zagreb. In Croatia, in fact, in the last decade floods occurred that have shown that levees are not absolutely secure and they can collapse due to the different situations. So the aim was to conduct a study and do technical documentation by which in the future unfavourable situations, like ones that happened before, will be prevented or reduced to a minimum. Although the conducted study is finished and was intended only for practical use, research is continued in particular in terms of safety and multiple criteria decision making and methodology and data collection.

2 Importance of levee assessment

Meteorological extremes in the area of upstream countries from Croatia recorded in 2010 formed a high water waves in the catchment area of the Neretva River, the Sava and the Danube, while large amounts of rainfall on the Croatian territory caused also the formation of high water of their affluent [2]. It was the flooding in September 2010 in the area downstream from the city of Zagreb that prompted the question of stability and security of built levees. Flood also started a series of dedicated measures for improvement of the built flood protection system with the purpose of reducing the flood risk to an acceptable level.
The importance of conducting levee assessment is in a monitoring, which is neglected when we talk about the levees in Croatia where there are neither regulations for the levee monitoring nor guidelines for the levees categorization. Joining the European Union, the Republic of Croatia committed to harmonize its regulations with a set of construction related standards, Structural Eurocodes. Today's information of levees in Croatia is based only on visual inspections and eventually on records in archives about anomalies during high water. For levees still there are no complete data on their heights. Of course in this situation there is also no data about foundation soil and soil that was used for building levees.
In many European countries there are standards for flood protection systems. In Germany and the Netherlands, standards have been augmented by national laws and regulations, while in the UK, investment in flood defense must meet the economic criteria in addition to prioritization criteria. In Poland, the local authorities are obliged to do levee assessment [3], because the majority of the levees are in their jurisdiction and that is regularly once a year and once every five years levee assessment includes investigations.
In the US and in the Netherlands, guidelines are prescribed to ensure levee safety. In these guidelines official checks are prescribed carried out by expert teams under the lead of key engineers with experience in investigations, design, construction and exploatation of levees. In the Netherlands, inspections or levee monitoring in order to evaluate the safety are mandatory by law. Levee assessment is carried out every five years and contains revision of the load, information on the building material and foundations, levee geometry and guidelines for the levee assessment, methods and criteria. U.S. Army Corps of Engineers (USACE) with the program for the safety of the levees aims to provide a better understanding, control and to reduce the risk of flooding associated with levees, along with maintaining and updating a national database of levees. Inspections of the levees are routinely each year and periodically every five years, when there is importance beside inspection to update the database.

After more floods [4] that emerged in the last decade in the United States, France, and all over the world reviews and research have been made to develop methods to model the levee failure mechanism and to assess performance of levees [5]. From the data collected in visual inspection, geotechnical investigations and from historical data indicators are established that can assess the state of the levee and its functionality. The issue of the levee safety, the way it evaluates levee, as well as the issue of the areas protected by levees are very important [6]. The way that may help in the planning of the monitoring, maintenance and remediation of levees and dams is proposed by identifying indicators and failure mechanism to which the individual indicators can lead [7], [8], [9]. The application of a new approach to assess the risk of flooding caused by levee failure was tested, as well as the model for the levee assessment [10].

3 Failure mechanism and levee state indicators

The aim of the research is to develop a methodology that will provide levee assessment and the failure mechanism. This primarily means collecting data. Data is collected from the existing documents, detailed visual inspections, investigation activities, in-situ and laboratory tests and numerical analysis. Data collected in that way are also the indicators that describe the state of the levee and possible failure mechanism. Visual inspection is preceded by collecting existing data and land surveying. The purpose of the visual inspection is to detect indicators that can affect the levee safety. Inspection includes the levee crest, waterside and hinterland slope and inundations and every anomaly is recorded. This is followed by preliminary investigations which include field and laboratory investigation works and serves for preliminary analysis. Detailed investigations are carried out in places where it is necessary to further investigate or where there is insufficient data. Assessment is carried out on the basis of the analysis of all data collected.

The basic idea of levee assessment is to collect data of foundation and levee. Investigations in this case enable exactly that, insights of the possible failure mechanism or deterioration of the levee performance. Adequate investigations and monitoring allows assessment of these conditions and give the possibility to react on time.

Otherwise, levees can come in five states that can cause the collapse. Each of the failure mechanism consists of several components and these components are registered by the indicators. Failure mechanism and indicators of each states are 1) overtopping, which represents the flow of water over the levee crest. The indicator of this condition is insufficient height of levees or levee is lower than the designed height, there is insufficient freeboard in relation to the high water or levee was lowered in relation to the design. 2) Erosion or any mechanism of erosion, internal or surface erosion, which threatens the integrity of the levee and leads to destruction. It can occur in the foundation or in the levee on the waterside or landside slope. It can be caused by high water, the fast water receding, changing the rainy and dry periods, wind, animals and human activity etc. Indicators of this failure mechanism are the surface material loss or lack of surface material and the movement of materials that includes sliding only the levee material (depressions, bulging, gullies, sliding) and movement of materials that includes sliding material from levee and foundation soil. 3) Seepage and internal erosion, moving soil particles and sand boiling due to the flow of water from the levee or out of the subsoil. Internal erosion can be caused by high seepage velocities or seepage through permeable soils. Indicators of this condition in levees are changes in vegetation, flow (constant or variable, clear or muddy) and loss of material, hydraulic instability. Figure 1 is showing the seepage through levee and foundation soil. 4) Sliding of a certain levee volume and / or foundation soil, moving along the sliding surface.

Figure 1 Seepage through an levee and foundation soil

Deep sliding surface may be caused by the levee upgrade. Shallow shearing on waterside or landside slope are the most common caused by pore water pressure increase, loss of soil strength due to equalization of pore pressures or due to erosion of levee toe on waterside. Translational sliding may be caused by large hydraulic forces at the contact of the foundation ground and the levee or due to drying of organic material in levee, which means reducing the weight and shear strength. It can also be caused by human activity when upgrading the levee or by liquefaction due to large seismic loads. 5) Settlement or compacting of levee material and foundation soil under self-weight or the levee weight. It may be the result of human activities due to levee upgrading, seepage, internal erosion in subsoil and as consolidation settlement.

4 Levee assessment objective

The objective of levee assessments or procedures that includes assessment is the permanent insight into the levee condition and the surrounding soil in terms of stability, permeability, and other actions on mechanical resistance and stability. By conducting the levee assessment all events and conditions that could affect the levee safety and the surrounding area can be timely notice and register. It has the purpose of determining whether the levee behaviour is in the normal range, or if there are deformations that could be a sign of disturbance in the structure, the foundations or nearby area. Next very important reason for conducting the levee assessment is the rational maintenance. Levee reconstruction is very delicate and expensive, and therefore, there is a need that all the damage and side effects are timely detected and solved while not yet acquired a larger scale. Figure 2 is showing the suggested guidelines for frequency of levee assessment.

The objective is both economic and maintenance which means long-term stability, security and sustainability. Maintenance costs and status of the construction are strongly linked. In order to achieve constant construction state maintenance costs are necessary. If the construction maintenance costs are low the construction itself becomes useless. In order to avoid the complete construction destruction in the late time point huge maintenance costs are necessary.

As well as the monitoring can promptly identify and register all the events and conditions that could impact the safety and surrounding area for what the monitoring is really important is the rational maintenance. Remediation of these structures is very expensive and it is important to identify and remove any damage in time.

Therefore, levee assessment, except that is a good measure for the levee condition also is important information on the planned long-term funding for the levee reconstruction. In order to obtain an overview of the levee behaviour it is appropriate to apply the full range of monitoring and technical and seismic monitoring hydrological and hydraulic monitoring. The levee

assessment is of great importance of collecting experience in order to improve the levee design and construction. The systematic levee monitoring that are in exploitation and the data obtained by investigations, measurements, and even a single visual observation, provides a great opportunity to be used for the purpose of designing, building and construction and exploitation of new levees.

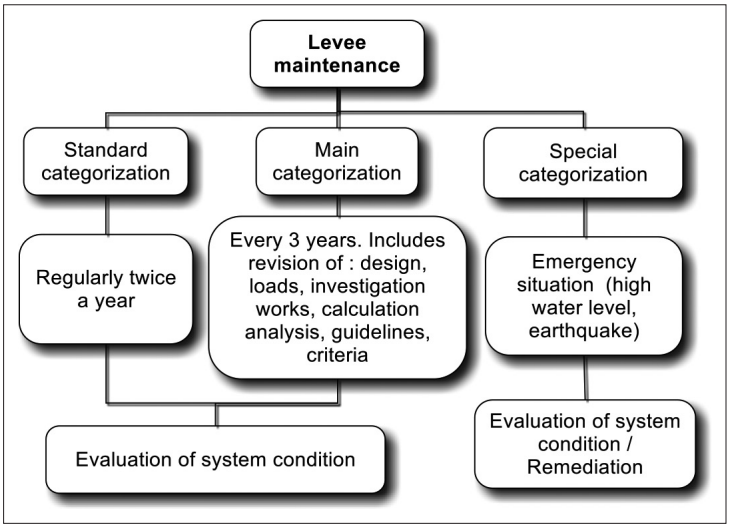

Figure 2 Guidelines for frequency of levee assessment [1]

5 Guidelines for the levee assessment

In order to ensure the proper levee functions during high water, for which the levee is designed caution, is needed. Levees are exposed to various actions and for that reason they need to be monitored. In addition, it is important to check whether the levee is maintained, as required, and provide all necessary information and all of the collected information, it is important to save. As the levees are linear structures geographical positioning data is important. Documentation on the levee assessment should be arranged and conducted in order to provide at all times a constant and complete overview of the levee. That includes a collection of all documents that are showing the actual levee performance and the overall levee assessment, the basis for the implementation of the results, as well as a collection of documents during the levee life time which are showing the levee condition set out by levee assessment. Levee dossier should look like and be based on the recommendations for the dam dossiers ''Rules for the monitoring of large dams'' [11].
Given that the part of the data is collected by visual inspection the water management patrol is one of the main to collect levee data. For this purpose, a method for training the water management patrol for the levee inspection is developed and in the near future the training should be carried out. Figure 3 is showing the investigation types of levee inspections by water management patrol. In this way the water management patrol will be trained which events, conditions or phenomena to be noted, how to write down the same, take photos and mark them on the locations and which are the further actions. The levee check list for the water management patrol is prepared. During the levee inspection the list of levee inspection should be complete. Taking into consideration the ratings given to certain levee elements it is possible to determine the final levee assessment. The state of each element is defined by the following assess.

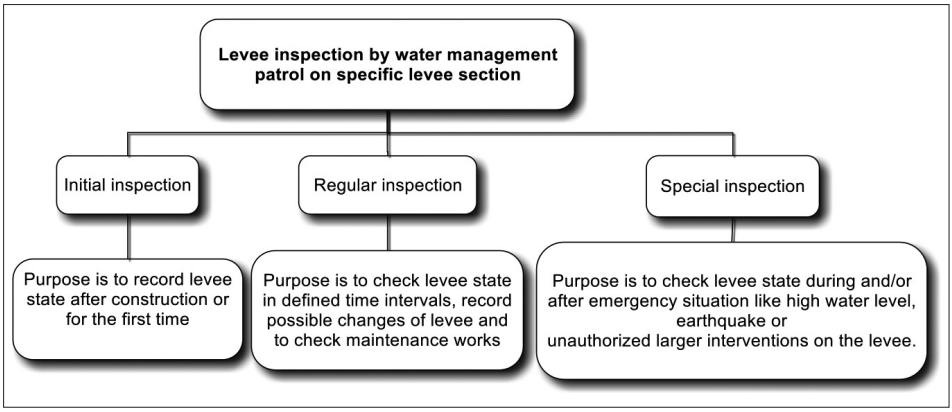

Figure 3 Types of levee inspection by water management patrol

After the initial, regular and special inspection by water management patrol, a report should be done. Report must include all materials and lists used when performing the levee inspection, levee photos, and especially photos showing the state of the levee and levee irregularities, site display with the markings of the locations evaluated as bad. It is necessary to state all the information on maintenance, indicate those which are carried out, which are running and the one to be performed. If the whole levee system is rated as acceptable in the report need to be specified which locations should be restored first in order to get the good levee condition and functionality.

Given the huge amount of data that should be kept for the levee lifetime GIS digital platform should be developed in which levee data are connected and available through geo-referenced platform. GIS would also enable faster access to information, more views on folders and thus to speed up the execution of necessary actions [6]. GIS will contribute to obtain a spatial decision support system aiding levee managers in their maintenance decision [5]. The main benefit of implementing a GIS dedicated to the management of flood protection dikes is obviously the preservation of information for the future [10].

6 Conclusion

Levees maintenance carries a lot of questions and a lot of decisions when it comes to levee reconstruction or just maintenance. Conducting the levee condition assessment helps in decision-making and defining priorities, suggesting a specific problem related to the levee condition and eliminates the effects of minor importance.

The main reason for conducting the levee condition assessment is primarily the population protection and the protection of material goods. It has the purpose of determining whether the behaviour of the levee is in the normal range, or whether there has been a phenomenon that could be a sign of disturbance in the levee, foundation soil or nearby area. As well as rational levee maintenance.

Levee reconstruction is very sensitive and expensive and there is a need that all damages and side effects are timely detected and solved while not yet acquired a larger scale. Since there are no national standards or legislations this paper provides guidance for levee condition assessment emphasizing the importance of using the same.

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