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Investigation of the Flow Field inside a Drainage System: Gully – Pipe – Manhole

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ABSTRACT

The performance of an urban drainage system largely depends on the linking elements of the system. Gully drop connected with manhole is one crucial structural part in several urban drainage systems. This paper will analyse the flow pattern and flow hydraulics of a gully-manhole linking element in a view of further research to investigate pollutant transport to the system. The overall aim of this research is to analysis the performance of urban drainage structures. Analysis will be done numerically using computational fluid dynamics CFD tools OpenFOAM® to simulate the gully-pipe-manhole. The Dual Drainage / Multi Link Element installation (DD-MLE) at the University of Coimbra hydraulic lab will be used to validate the numerical simulations. The experimental model setup consists of a 0.5 m wide channel, a 0.6 × 0.24 × 0.32 [m] (L × W × D) gully, a gully outlet with an 80 mm diameter pipe and a manhole of 1 [m] diameter and upstream and downstream pipes connecting manhole. The flow pattern is observed under drainage flow conditions.

Keywords: *Computational Fluid Dynamics (CFD), Urban drainage, OpenFOAM®, Gully-Manhole*

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Increasing Piano Key Weir Efficiency by Fractal Elements

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ABSTRACT

Piano Key Weirs (PKW) are hydraulic structures which can be used for flood release systems on dams or for in-channel weir replacement. The efficiency can be increased compared to regular weirs, since the effective overfall length will be majorly increased by arranged piano keys. The present research investigation deals with experimental model results of scaled PKW models and compares resulting discharge coefficients and scale effects. One PKW geometry will be manufactured with included fractal elements with the main aim to increase the structure's efficiency. The paper includes detailed information on the investigated experimental models and their results. Additionally, the paper focuses on future concepts and possible PKW adaptions.

Keywords: *Piano Key Weir, PKW, discharge coefficient, efficiency, fractal elements*

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Numerical investigation of the pressure on a spillway crest

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ABSTRACT

Understanding the pressure distribution on a spillway crest can help to improve their design. In this frame, we propose a finite difference method for irrotational flows. Our method, based on a previous work, determines the free surface iteratively. For best results, the computation of the velocity and the pressure at the free surface is done by a bi-dimensional function fitting. The evolution path is determined by numerical derivatives of the pressure at the surface. The iterative method is tested on a subcritical flow. The pressure computation is compared to experimental measurements of the pressure on a spillway crest. Both results are very encouraging: the free surface moves smoothly to an equilibrium state and the pressure on the structure is very close to experiment. For this last point, the method is also able to faithfully reproduce pressure drops.

Keywords: *Finite difference, Spillway, free surface, potential flow*

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Prediction of Hydraulic Jump location in Some Types of Prismatic Channels using Numerical Modelling

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ABSTRACT

The numerical modelling of free surface flows is important to understand their behaviour and predict situations that may occur. The Saint-Venant equations are most commonly used for practical modelling this type of flows. There are many methods and numerical schemes used for the solution of these equations. In our work we used the 1D Saint-Venant equations and the MacCormack finite difference method with TVD extension scheme to calculate flow depth and velocity and the location of the hydraulic jump which is formed in prismatic sloped channels with different sections, such as rectangular and triangular sections. The extension TVD plays an important role in minimizing the oscillations of the flow in the channels.
We used MATLAB® as a programming tool, to simulate several flows based on experimental trials that allow us to impose different upstream water depth and velocity (Froude number) and we were able to analyse location using characteristics of a hydraulic jump such as conjugate depths. We present a matrix of flows ranging Froude numbers from 3 to 8, initial depth from 0.035 m to 0.05 m and velocities from 1.3 m/s to 4.5 m/s. Results are better for low slopes as expected and the changing of slope and Froude number has a relation with the location of the hydraulic jump.

Keywords: *Saint-Venant equations, hydraulic jump, triangular channels, MacCormack scheme, free surface flows*

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Inlet capacity of street inlets with partial severed grate openings

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ABSTRACT

Due to an increasing number of extreme rainfall events managing urban flooding requires new design approaches concerning the underground drainage system as well as the temporary surface water runoff. Latest developments on bidirectional coupled models, 1D-1D as well as 1D-2D models, are still employed in practice. Connecting elements between the surface and the underground system are street inlets – offered in different construction types and designs. Depending on the longitudinal and transversal slope of the street as well as the street inlet type the hydraulic efficiency of grate inlets is hardly available, thus, physical model test runs were done. Due to steep longitudinal slopes up to 10 % only supercritical flow conditions occur with flow depths up to 3 cm and flow velocities of approximately 1 – 2 m/s. In previous physical model test runs the overall grate capacity of selected grate inlets was measured. The aim of the present paper is to investigate the inflow conditions in detail. Severing defined parts of the grate openings the main inflow regions with their efficiency can be determined – depending on the flow velocities and flow depths upstream of the inlet. A typical street inlet used in Germany is investigated. The grate inlet openings are divided into eight parts where the intercepted flow is measured for each part separately. The main inflow areas of the grate inlet are located in a typical triangular pattern on the curbside. In order to calibrate and validate a numerical model to calculate the efficiency of street inlets the physical model results were compared to the numerical results.

Keywords: *street inlets, inlet capacity, supercritical flow, urban flooding*

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Vertical Slot Fishway: Evaluation of numerical model quality

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ABSTRACT

Numerical modeling is taking a growing part in constructing complex hydraulic structures. Especially structures where a standard design or an analytic calculation isn't applicable, numerical investigations can provide important knowledge of flow parameters.
Fish passage structures are subject of research investigations for several decades but still not extensively described. Vertical Slot Fishways have shown a wide application range and are well documented. But particularly for slight slopes less than 5 %, which is needed for most fishes in Europe, fundamental knowledge is leaking. Numerical modeling can provide a cost-effective tool to investigate flow on VSF.
The present paper deals with an investigation on quality components of numerical 3D simulation of VSF. Four pools constructed as standard design are modeled and examined. A Large-eddy simulation, second order, with three various mesh resolutions was used. The study focused on velocity fields, flow patterns and flow depths, being affected by mesh resolution.

Keywords: *Fish passage, vertical slot fishway, numerical modeling*

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Nappe Vibration Characteristics for Free-overfall Structures

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ABSTRACT

Under relatively low-head discharges, the occurrence of nappe oscillation, otherwise known as nappe vibration, may be observed on hydraulic structures with a free overfall, such as weirs, crest gates and fountains. This phenomenon, which has been early identified as undesirable and potentially dangerous on gates, is characterized by oscillations in the thin flow nappe cascading downstream of the crest. In addition, these oscillations produce a significant level of noise and acoustic pressure waves that increase the environmental and societal impacts of the structure. A review of the scientific literature shows a lack of consensus regarding the causes and source of the oscillations development. In this context of relatively poor understanding of the dominant processes, a detailed investigation has been undertaken to identify and quantify the nappe vibration mechanism. The research is being performed with a prototype-scale linear weir located at the Engineering Hydraulics laboratory of the University of Liège. The study employs high-speed cameras and audio equipment to characterize the nappe vibration. This paper presents first characteristics of the nappe vibrations gained from images and sound analysis, especially in terms of vibration frequency, for a quarter round and a half round weir crest.

Keywords: *Spillway, nappe vibration, nappe oscillations, physical modelling, flow characterization*

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Water wave measurements at Bellsund in the western Spitsbergen

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ABSTRACT

Arctic region has experienced rapid changes in the last few decades. The Arctic coasts in times of progressing global warming are exceptionally vulnerable to erosion. Arctic sea-ice extent is decreasing dramatically leaving coasts exposed to destructive action of waves. The lack of sea ice causes a dramatic increase of wave energy.
In order to provide insight into coastal changes in Arctic areas, field measurements were carried out in the area of Calypsobyen, Bellsund, west Spitsbergen. Data of free-surface elevation, wave orbital velocities, water currents and bathymetry were collected during expedition in the western Spitsbergen. In the frame of this study a detailed analysis of wave field and bathymetry were performed. The collected database constitute unique and valuable source of information on Arctic wave climate.

Keywords: *Field measurements, Arctic, water waves, database.*

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Large Eddy Simulation of the water flow around a cylindrical pier mounted in a flat and fixed bed

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ABSTRACT

The main goal of this study is the numerical simulation of the 3D turbulent flow around an isolated cylindrical pier, a generic case that is relevant for the study of flow and scour around bridge piers. In this contribution, only a fixed and flat bed configuration will be considered, representative for the beginning of the scour process. A Large Eddy Simulation (LES) model has been set up in Ansys Fluent, aiming at the simulation of the flow around the cylinder previously studied by Particle Image Velocimetry (PIV) in the lab experiments of Nogueira et al. (2008). The main focus will be on time-averaged velocity and vorticity fields, the bed shear stress and the drag coefficient of the pier.

Keywords: *CFD, LES, Ansys Fluent, cylindrical pier*

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Coupling Process for 1D-2D Numerical Flash Flood Simulation: A Parameter Study of Involved Variables for Gullies and Manholes

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ABSTRACT

Urban flash floods and their hydro numerical coupled modelling is influenced by various parameters and assumptions for model setup and implementation. Hence, the present paper deals with coupling details of 1D-sewer and 2D-surface models. Involved hydraulic parameters will be analyzed concerning their influence on computed results for flood levels and the discharge rate (bi-directional) between both, 1D and 2D, model approaches. Additionally, flood durations will be investigated. Involved parameters are the inlet area, the limitation of the discharge capacity according to Ras-Ew and the discharge coefficient. Comparisons of limited and unlimited numerical computation for discharge capacity at the coupled nodes show that the flood duration will be more influenced than flood levels. The quantitative exchange at each node is calculated by using the Torricelli approach and including variable parameters. Analyzing flash floods with coupled numerical models, allows the implementation of measures and their evaluation regarding flooding depth and thus security against flooding. Exemplarily improvements will be shown. Additionally, the model is primarily evaluated by comparing the model results with measurements in the sewer system.

Keywords: *gullies, flash flood, coupled numerical modeling, parameter study, discharge coefficient, inlet capacity.*

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Analysis of clearance gap losses on the hydraulic pressure machine

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ABSTRACT

The Hydraulic Pressure Machine (HPM) is an energy converter to exploit head differences between 0.5 and 2.5 m in small streams and irrigation canals. The HPM looks similar to a classic breast shot water wheel but has a smaller number of blades, a relatively large central hub and the wheel runs at variable speeds (2 to 12 min^{-1}). Preliminary results show that the HPM is an economically and ecologically viable technology for small hydropower generation. The clearance gap between the blade tip and the shroud at the bottom of the wheel is very important regarding power losses. A theoretical approach has been developed which considers a stationary wheel to quantify the leakage losses. However, no validation of this theory has been done. The goals of this research are to quantify the leakage at operating condition and to improve the HPM blade design to further reduce gap losses. Thus a large scale physical model is tested at laboratory conditions. The HPM model is 1.1 m in diameter, 0.8 m wide and has 12 flat blades. Variable blade tips machined from steel and EPDM rubber are investigated with gap sizes of 1, 5 and 10 mm. The physical model results show that the flow rate passing the wheel during operation is approximately one third of the flow rate calculated by the theoretical approach. The variation of different gap sizes reveal the importance of small clearance gaps to reach high efficiencies.

Keywords: *Small Hydropower, Gap Loss, Hydraulic Pressure Machine*

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Experimental and theoretical studies on the formation of freak waves over a sloping bottom

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ABSTRACT

Precise prediction of waves and their interactions with structures is of significant importance for coastal and offshore engineers. Information on the propagation of water waves and wave interaction with structures can be obtained from available models. Far less information is available on extreme waves and their impact on coastal and offshore structures. In fact, the knowledge on the propagation of extreme waves and the attack of extreme waves on coastal and offshore structures is in an infancy. In this study experimental and theoretical investigations were conducted to provide insight into the physics of the formation and evolution of extreme waves. A series of laboratory experiments were conducted in a wave flume of Institute of Hydroengineering Polish Academy of Sciences to study the formation and transformation of freak-type waves over a sloping bottom. The studies are supported by theoretical investigations. Results indicates that sloping bottom has a substantial effect on the formation and evolution of freak waves in a wave train. The relevance of the results for practical applications is commented.

Keywords: *freak waves, coastal structure, sloping bottom*

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An investigation of the velocity field over rippled sand bottom

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ABSTRACT

Ripples at the sandy seabed are the consequence of the oscillating movement of water particles. They are the reason for the increase of the roughness of the bottom becoming an important factor in the sediment transport process. Better understanding of the processes taking place in the near-bottom flow field will allow accurate description of the mechanism of sediment transport. An investigation of the velocity field over rippled sand bottom has been carried out in a wave flume of the Institute of Hydro-engineering of the Polish Academy of Sciences in Gdansk. Measurements were performed by using the technique of Particle Image Velocimetry (PIV). Both vertical and horizontal components of the sandy sediment velocity field were measured in the region immediately over the bottom coated by sand ripples. The results obtained describe the instantaneous velocity fields of non-cohesive sediment particles constituting the bedload, and of water particles. It has been demonstrated that the PIV technique of measuring the movement of sediment particles at the bottom proximity has proven itself as a reliable and accurate method.

Keywords: *Sediment movement, sand ripples, velocity field, PIV method*

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Feasibility Study and Optimization of the Structural Design of Locks made out of Plain Concrete

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ABSTRACT

Modern ship locks are made of steel reinforced concrete. A crucial issue, similar to other hydraulic structures, is the intensive exposure to water and therefore consequently the contact to a highly varying physical and chemical environment. This may cause rapid deterioration of the concrete cover due to the ingress of chloride, oxygen and moisture leading to excessive corrosion of the embedded reinforcement. Consequently, a strong decrease in structural strength is inevitable. Against this background a study was conducted in which only a plain concrete structure was considered. This construction method had been used successfully in former times and was then replaced by reinforced concrete constructions in the 1960s. The study considered a typical concrete ship lock structure without any reinforcement, with length of 190 m, width of 12.5 m, a fall of 10 m. The structural analyses are focused on the lock chamber walls as they are the most labor and cost intensive components rather than on the lock head and gates. The structural and geotechnical verifications were conducted in accordance to latest Eurocodes and German standards along with Finite Element Analysis using ANSYS. The structure was designed for three extreme operating conditions depending on different water level inside the chamber. Furthermore dimensional optimizations are preformed using linear programming varying the groundwater level, concrete and soil type. The findings suggest that the most critical loading condition is when there is no water in the chamber. In this case abase length of 13.28m is required to reach sufficient stability. However, the bearing capacity of soil and the tensile strength of the concrete are the most critical parameters for fulfilling the safety checks for this type of structure.

Keywords: *Ship-Lock Structures, Plain Concrete, Static Structural Analysis, ANSYS, Feasibility, Optimization*

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Interfacial velocity estimation in highly aerated stepped spillway flows with a single tip fibre optical probe and Artificial Neural Networks

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ABSTRACT

Air-water flows can be found in different engineering applications: from nuclear engineering to huge hydraulic structures. In this paper, a single tip fibre optical probe has been used to record high frequency (over 1 MHz) phase functions at different locations of a stepped spillway. These phase functions have been related to the interfacial velocities by means of Artificial Neural Networks (ANN) and the measurements of a classical double tip conductivity probe. Special attention has been put to the input selection and the ANN dimensions. Finally, ANN have shown to be able to link the signal rising times and plateau shapes to the air-water interfacial velocity.

Keywords: *air-water flows, Artificial Neural Networks, air-water interfacial velocity, stepped spillways*

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