International Junior Researcher and Engineer Workshop on Hydraulic Structures Session 5

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SESSION REPORT

SESSION 5

Chairman: Mohanad Khodier
Rapporteur: Adam Witt
Advocatus diaboli: Maria Trujillo
Speakers: Iordanis Moustakidis, Francois Rulot

ROUND TABLE

Moderator: Fadi Wakim
Rapporteur: Adam Witt
Session Chairman: Mohanad Khodier
Session Speakers: Francois Rulot, Iordanis Moustakidis (had to leave)
External Expert: Brian Crookston
Other Participants: K. Warren Frizell, Boris Rodriguez, Fabian
**1st Presentation**

**Title:** THE EFFECT OF BOULDER SPACING ON FLOW PATTERNS AROUND BOULDERS UNDER PARTIAL SUBMERGENCE

**Author(s):** Iordanis Moustakidis, Athanasios Papanicolaou, Achilleas Tsakiris

**Speaker(s):** Iordanis Moustakidis

**Brief description of author(s) approach:**

There are many benefits to the use boulders in restoration projects. Boulders create more spawning grounds, resting areas and feeding areas for fish populations. When considering dam removal, boulders can be used to regulate sediment transport. However, there is a big limitation in the current knowledge of boulder use – there are no guidelines on optimal spacing of boulders in streams or how many to put in the river. Additionally, very few studies to date have examined the interaction between boulders and the surrounding flow. Difficulties arise in implementing acoustic instrumentation (high turbulence, boundary reflections, boundary interference, bubble flows increase noise). This study presents the experimental results of a new technique, infrared (IR) thermal camera imaging, in capturing the surface flow structures developing around neighbouring boulders within an array of boulders through temperature differences. The hypothesis of the study is that boulder spacing controls the developing flow structures around partially submerged boulders. The objective of the study is to map the surface flow structures around boulders within an array under low relative submergence regime. Two scenarios are studied – increased roughness regime from close spacing (6d), and from far spacing (10d). The IR camera recorded flow with hot water droplets used as tracers. Results showed the IR camera successfully records motion of water surface temp distribution.

**Questions and answers:**

**Roundtable discussion feedback**

Q: How are you planning to find shear stress or scour from surface values?
A: These values need additional hydraulic parameters to accurately estimate.

Q: Your images showed two kinds of motion – advection and heat diffusion. Those two motion patterns are governed by different equations. If he is only on surface determining velocity of flow, how does this compare to sediments and shear stress?
A: It seems like hot water droplets on surface are pretty discrete and don’t really mix well. The diffusion of heat is more than just from within fluid because you have action of air above surface as well. Have you considered adding hot water from bottom so there is homogenous flow?
Q: Results were so dependent on being close to injection, might not be true picture of flow dynamics, maybe modifying the flow structure by even a little bit.
A: It would be good to look at time scales over which advection and diffusion take place. Correct estimates of these scales may validate his camera placement.

Q: In context of river restoration or enhancing fish habitat, composite roughness of rocks is different than racquetballs. Velocity profiles may be different.
A: From biology standpoint, may not want uniformly placed boulders. Would be surprised if the biologists said place these in uniform spacing. Bigger picture thought.

Additional Comments:
Maybe put the camera to give a cross-section view. This may give better insight into submergence.

Did well with his presenting. Good presentation skills.

Q&A from original presentation

Q: Where does this end up as far as a contribution? Alternative means to estimating flow roughness as result of boulder at different submergence?
A: We know resistance is connected ot spacing between boulders. Focused on flow patterns in this study, how can we map those patterns. Tried to do something similar, difficult to build velocity field distribution. Test a different camera. Map flow structures, see how that affects depositional patterns.

Q: Plots of momentum, which plane?
A: Surface, time averaged. Video lasted 30 seconds, 30 fps. Not symmetric since there is interference between emanating shear layers form boulders.

Q: How repeatable? Chaotic system, repeat image?
A: Took a lot of videos. Sure they have uniform flow conditions upstream, start taking measurements. At least 15-20 videos they analysed. Videos are pretty similar. Some variation in 6 spacing, suspect that has to do with interference. It is random event, but they put hot water in certain way, everything was repeated identically.

Q: When you varied boulders size, see difference in recirculation region depending on spacing?
A: Haven’t tried, uniform boulder size.

Q: Have you tried non-uniform spacing)?
A: No, former studies have shown different spacing is sufficient to create roughness regime.

Q: Results, do you show that shear layers are good at altering bed shear stress? What is influence of spacing on shear stress?
A: Yager paper describes in more detail.

Q: Does this technique capture free surface with air entrainment?
A: Record an outlet in river, able to capture the water that was coming out from the outlet into the river, how that interfered with outlet into river. Can transform when camera is at an angle, yes, they can do that. Used standard 30 fps, not sure if the camera can capture the frequency of surface waves.

Q: Other work in Germany on boulder spacing, measured forces in boulders, observed interference.
A: Glad to hear.

Q: Temperature difference between hot water and flume? How does diffusion of heat not captured by camera versus flow velocity? Reference paper that diffusion is significant, not capturing that but flow pattern.
A: Flume variation was 10-15 degrees. Hot water was 45 Celsius. Camera was placed just upstream from the hot water seeding area.

Q: Does number of optimum frames depend on flow?
A: Has to do with analysis of grid of recording videos. About 900 frames. To avoid analysing all 900 frames, find optimum value of analysing frames. By changing flow, number of frames required to analyse should not change.

Q: Injection of hot water was close to inlet, what is close, will you test the influence of distance on diffusion?
A: If you put too close, you have just a bright color, white on IR camera, all over picture, can’t analyse. If you put hot water upstream, won’t have any hot water flowing in the camera vision. Need to find spot where it will not affect your measurements. Found it, close to 0.5m was optimal. By changing position, accuracy of velocity field changes. Tried different distances.

Q: Would heated rod element work instead of hot water drops?
A: Read paper on that, I don’t recall results. Hard to build that in flume.

Rapporteur’s appreciation:

The objective of this paper was to present a new technique for estimating flow structures around boulders in an array. The technique appears to resolve several issues that persist in acoustic measurement devices. However, the accuracy of the technique needs to be explored further and validation of the technique could be more robust. Most of the discussion revolved around the use of hot water droplets as tracers, and more specifically the placement of the droplets within the flow, the diffusion of heat and ways to improve flow visualization using hot water as a tracer. The presentation clearly laid out the results of the experimental research, and significant care was taken to provide concise results,
conclusions and objectives for further research.
Title: DEALING WITH SEDIMENT TRANSPORT OVER PARTLY NON-ERODIBLE BOTTOMS

Author(s): Francois Rulot, Benjamin Dewals, Pierre Archambeau, Michel Piroton, Sebastien Erpicum

Speaker(s): Francois Rulot

Brief description of author(s) approach:

Presented a numerical method that can handle sediment transport over partly non-erodible bottoms. Non-erodible means bedrock in river or concrete structure in river. Sediment transport is modified by manmade structures, which can lead to critical consequences like scour or sedimentation of reservoir. The current problem is that the cells in the finite volume numerical model can become negative in explicit scheme. Exner equation describes sediment transport for erodible bottoms and can apply to non-erodible bottoms, but a correction is required. He used a 2D horizontal model, finite volume method, with a correction for non-physical results through an iterative process. Two processes were modelled – the evolution of a trench over a fixed bump, and the evolution of a head of sediment on a flat fixed bottom. Each had experimental benchmarks used to validate the model. Sensitivity tests show that the velocity of the sediment heap is directly linked to water discharge; height of crest is directly linked to the initial sediment heap height. Results showed that volume conservation was respected, the matching of numerical results to experimental results was good, and that increased computational time was limited compared to the simple reset method.

Questions and answers:

Roundtable discussion feedback

Q: Have you considered a different sediment transport method other than Meyer Peter-Mueller formula?
A: MPM is universally accepted as reasonable sediment transport method, but shear stress values may be more sensitive to various methods of calculation, which could modify your computational results.

Compute height and length of the dune as it propagates down the channel to validate the model using an additional method.

Notation may be a bit complicated, confusing when going between y and z in 2d.

Q: How can you account more for 2D variations in the flow?
A: Account for wall shear forces? This is a complicated phenomenon, 3D naturally. Flow
at downstream boundary is very three dimensional. Can try to put small corrections in shear stress term, in some way account for angle of attack. May try accounting for momentum equation. Not sure how this will affect computational time.

Q: Not clear why you have to correct the negative volumes. Why does that happen?
A: Exner equation is used for whole domain that can be erodible. Can use the same equation for impacted area. Have to correct because in the equation nothing says there is a non-erodible bottom.

Q: You used \( dx = 10 \) cm, did you look into smaller ones?
A: Tried using different sizes, came up with results that were not representative of physical results.

Q: Did you see instabilities when the water goes up and down?
A: No.

Q&A from original presentation

Q: What is the size of particles used?
A: In second example, size of particles were 2.8 mm, in first size of particles is not important in numerical method, used power law of water.

Q: What was given numerical scheme?
A: Finite volume technique.

Q: Solution is 2d in horizontal plane, why use power law for velocity?
A: Only in first benchmark used power law, was used in previous study. Gives coefficient for sediment transport based on that. Compared with his results. Power law to compute sediment flux, just to compute sediment fluxes as function of mean velocity, not used in model.

Q: Experiments interface at sediment and water attaches almost immediately to boundary at end of bump. Depth averaged but flow behind bump may be 3d.
A: Yes, vertical velocities play important part downstream. Spatial resolution in that area was \( dx \) of 10 cm.

Q: Could that be measurement error in moving bedload layer as elevation. In model it says no depth.
A: Yes.

Q: Experimental studies, measurements were taken in central flume. Did you measure in center of flume? Did you notice any influence of walls on shape?
A: Small influence of walls because sediment deposits.

Q: Regarding separation between \( q \) bottom and \( q \) gravity, does particle fall?
A: Critical slope at which sediment falls; gravity is only contribution at that point.

Rapporteur's appreciation:

The author was able to show reasonable agreement between the new CFD method and experimental results. Much of the discussion focused on the 3D characteristics of the flow, how an accurate model would include these effects, and how difficult it would be to actually implement and calibrate this model. Suggestions were given for smaller modifications that may improve the accuracy of the results. Given the work that has been put in and considering future computational effort, these smaller modifications are likely the most efficient direction for future research.