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Review and rebuttal of the paper

Investigating hydraulic loads on a crossbar block ramp using two different computational fluid dynamics models and a physical validation model

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Editor handling the paper: Sebastien Erpicum

The reviewers remain anonymous.

1 Second round of review

1.1 Reviewer C comments

The authors addressed most of my comments. And the version was improved. I think another minor revision is necessary to correct some errors. Especially the figure's quality could be improved; e.g. checking font sizes compared to text size and checking parameters. This can be clarified with the editor.

Minor:

2: parameters should be slanted, same for Fig. 6 and 7; and all other e.g. where you are mentioning Q1 etc.

P4, L5: Q1 etc… number should be an index. Number not slanted. Same for q. Check entire document

Chapter 3: do not start writing without a subsection and the include 3.1. Otherwise start with '3.1 General'…

1.2 Authors responses to Reviewer C comments

We made the final format changes as requested by reviewer B, inserted author details, reduced white space and finalized the figures.

Unfortunately, we've noted an erroneous sentence in section 3.3.1, p. 13, which we aimed to correct in the last version. However, the change was missing from the document we have uploaded. We corrected it now by changing the text from (old):

"Both results for Q2 does agree well with studies reporting the critical loads in R2 (Sindelar 2011; Sindelar and Smart 2016), as the flow for Q3 (whose regime is visually more in R3) indicates that critical loads can also occur between R2 and R3."

to (new):

"Both results do agree well with studies reporting the critical loads in R2 (Sindelar 2011; Sindelar and Smart 2016), considering that the flow for Q3 is between R2 and R3."

In addition, we

- inserted the Appendix directly at the end of the Manuscript text to ease file handling.

- converted Citavi fields to text to make them more robust

- kept hyperlinks from the text to references and figures

If possible, could you make sure that bookmarks (for the chapter headings) are included in the final PDF (like in JCHS Paper 20), because we find them very useful.

2 First round of review

2.1 Editor comments

Comment	Addressed?	Response
1. Please revise your paper in order to deliver a clear message on how CFD should be applied to model block ramps…	Yes	Generally, our study is not capable to derive application rules valid for all possible boundary conditions. Rewritten introduction and added information to objectives and conclusions to make them more clear and interesting. Also, added introductory sentence in chapter 3 to help the reader distinguish between model testing (section 3.1+3.2) and load prediction analysis (section 3.3). Rewritten parts of the discussion and added a new Appendix to render the information provided more useful and comprehensible.
2. ... and to better justify your choices, specifically - simulations performed at physical model scale and not at prototype scale…	Yes	The CFD simulations were performed at model scale to ensure full comparability. Added explanation on p.3 LL14-15. As suggested by Reviewer C, additional simulations in prototype scale would be helpful to analyze possible scale effects. However, we decided to save this effort for future work due to temporal limitations and the estimation that advection and turbulence are way more important than air bubble effects here. Added assessment on p. 16, L33. See also response to Reviewer C comment #1.
3. - mesh size (while a grid sensitivity analysis should be provided)…	Yes	The mesh size according to LES requirements was determined based on estimation, experience and available computational resources. It proofed acceptable in comparisons with the physical model, y+, and with respect to TKE resolved vs. total TKE. Added descriptions of the procedure in Methods, a comment in Results/Discussion (section 3.2.3) and the check results in a new Appendix.
4. - use of same mesh for both CFD models	Yes	We created the mesh for LES requirements and re-used it with RANS. While this approach produces unnecessary high computational cost for RANS, it ensures full comparability. Added explanation in section 2.3.1.

2.2 Reviewer A comments

The authors focus on the simulation of 3 specific discharges in a crossbar block ramp, presenting results from different simulations using RANS and LES, as well as physical models. This topic is of interest to the field, although the objectives are not clear.

The paper is properly organized, concise, and is clearly written , fitting to standards with correct grammar and syntax. All illustrations are useful and of acceptable quality. However, size should be scaled and in Figure 1, I don't think that " flow section" is appropriate (could be Flow area). Also in Figure 7, the water level envelope curves for the physical model is not clear and Figure 11, graphs should be superimposed and the 3 boxplots in the same CR should be associated with the flow. Appropriate and complete keywords are provided. Appendix are irrelevant.

Literature review is basic, referring some of the interests of crossbar block ramp, its mainly regimes and its main characteristics, as well as common approaches in CFD, without details, justification or examples of application. Concerning block ramps, nothing is mention about velocities, energy dissipation, friction factor and other characteristics that can be important in the different regimes. Since the name "crossbar block ramp" is not unanimous in the literature, also called cross beams, … references may be not complete. I did not check all the references. Regarding CFD, although distinct models were used, the choice of solvers within OpenFOAM® was not justified and model applications were not consistent. No mesh analysis is presented and results from RANS and LES are presented from the same mesh, which is not logical theoretically. Perhaps a literature review or a deep study of turbulence models and what a specific model represents would be didactic and enriching.

The forces are well represented in the Figure 6 and the pressure zones in the Figure 3c). However, the procedure is not clear. The data analysis procedure for each model, RANS and LES, is not presented and should not be the same. A sound methodology and correct mathematics are not presented with the exception of delta, for which the only mathematical formula is presented.

The discussion of the results is not deep enough. Non-direct results are justified with waves, with conclusions based on other results not presented in the paper.

No specific novel aspects are treated in the paper. It presents obvious conclusions regarding the models and uncertain regarding loads on the crossbars.

2.3 Authors responses to Reviewer A comments:

Comment	Adressed?	Response
1. Figures - All illustrations are useful and of acceptable quality. However, size should be scaled…	Yes	Reduced Fig. 1 size to 80 %; Fig. 6 size from 30 % to 20 %; and Fig. 7 from 94 % to 85 % to level font sizes.
2. … and in Figure 1, I don't think that " flow section" is appropriate (could be Flow area)	No	The three sections identified change over just 1 dimension, i.e. length. "Area" could wrongly be associated with a change in two dimensions, the same goes for e.g. "zone". The alternative "segment" sounds more like a part of a firm object, so we decided to go with "section".
3. in Figure 7, the water level envelope curves for the physical model is not clear	Yes	Not sure if the comment is about the meaning of "envelope curves"? Added "(extreme values)" to figure 7 caption, and removed the misleading word "curves", see https://en.wikipedia.org/wiki/Envelope_(waves)

4. Figure 11, graphs should be superimposed and the 3 boxplots in the same CR should be associated with the flow	No	In section 3.3 and figure 11, we aimed to shift the focus from model evaluation to flow regime/load analysis. Therefore, we split the RANS and LES model results. This is also useful because the previous chapter has shown the deviating quality of the two model types. Hence, we left Fig. 11 unchanged. Still, we rewrote section 3.3.1 to make the distinction clearer.
5. Appendix are irrelevant	Yes	Removed previous Appendix with numerical schemes.
6. Introduction - Literature review is basic, referring some of the interests of crossbar block ramp, its mainly regimes and its main characteristics, as well as common approaches in CFD, without details, justification or examples of application. Concerning block ramps, nothing is mention about velocities, energy dissipation, friction factor and other characteristics that can be important in the different regimes.	Yes	Added details from Sindelar and Smart (2016) including the method. Reordered and rewritten the Introduction with improved wording (e.g. stone → boulder) to better outline the current knowledge and to better guide towards our objectives of identifying flow regime and position influence on crossbar loads and evaluating CFD methods for a large parameter study. See also response to next comment.
7. P 2 , L 7ff - Since the name “crossbar block ramp” is not unanimous in the literature, also called cross beams, … references may be not complete.	Yes	We tried to express our awareness of the many different terms used for the structure investigated in L 7. We performed our literature study using all relevant terms, including "cross beams", "block ramp", "step-pool rock ramp". In the first paragraph, we added a sentence and references about hydraulically related concept with different purposes. On further note, we added two relevant recent papers that were published during this review (Zhang et al. 2022 and 2023).
8. Methods - Regarding CFD, although distinct models were used, the choice of solvers within OpenFOAM® was not justified …	Yes	In OpenFOAM, two solvers (interFoam and interIsoFoam) are capable to capture an unsteady free surface and air entrainment. Preliminary tests confirmed that interIsoFoam yields a sharper interface (as expected) at similar computation time. Added this piece of information on p. 6, LL 15-16.
9. ...and model applications were not consistent.	Yes	We aimed for full consistency including the mesh between the two CFD models. The only difference is the turbulence model and the according numerical schemes. Sampling was started just after any possible initialization effects were gone. We made that more clear in section 2.3.1 and 2.3.3. The different initialization procedures (section 2.3.2) were chosen to save computation time and do not affect results, as the sampling interval was only started after reaching Q equilibrium.

10. Methods - No mesh analysis is presented…	Yes	See response to Editor comment #3. Added analysis for y+ (for wall functions) and resolved TKE (in LES) in the Methods and a new Appendix..
11. …and results from RANS and LES are presented from the same mesh, which is not logical theoretically.	Yes	We used the same (LES-suitable) mesh for consistency despite the additional cost in RANS, see response to Editor comment #4.
12. Methods - Perhaps a literature review or a deep study of turbulence models and what a specific model represents would be didactic and enriching.	No	Studying numerics in more detail than already presented could help to understand our results. However, this would not contribute to our objectives of supporting design decisions by quantifying value and location of maximum crossbar loads.
13. Fig 6 - The forces are well represented in the Figure 6 and the pressure zones in the Figure 3c). However, the procedure is not clear.	Yes	Added explanation of force and moment calculation in section 2.3.3.
14. The data analysis procedure for each model, RANS and LES, is not presented and should not be the same.	Yes	In fact, the procedure is identical for both models for full comparability. We made that clearer in section 2.3.3.
15. A sound methodology and correct mathematics are not presented with the exception of delta, for which the only mathematical formula is presented.	No	As our objectives are directed to practical application of CFD models to improve crossbar block ramp design, we decided to omit well-known equations, e.g. the Navier-Stokes equation. Because our CFD code, OpenFOAM, is Open Source, the reader has the opportunity to directly check the implemententation of the equations, which seems to be more strict than to trust in the correct implementation of a written equation.
16. Dicussion - The discussion of the results is not deep enough. Non-direct results are justified with waves, with conclusions based on other results not presented in the paper.	Yes	Rewritten section 3.3.1, removed the reference to results not shown. Added new reasoning based on figure 11 and reference to results of Sindelar and Smart (2016) instead.
17. Conclusions - No specific novel aspects are treated in the paper. It presents obvious conclusions regarding the models and uncertain regarding loads on the crossbars.	Yes	Rewritten conclusions to underline relevance for readers (i.e. peak moment also between R2 and R3) and removed one bullet point containing a simple confirmation of an earlier result of Sindelar and Smart (2016).

2.4 Reviewer C comments

Review: Investigating hydraulic loads on a crossbar block ramp using two different computational fluid dynamics models and a physical validation model

The paper deals with numerical models and a validation experimental model for crossbar block ramp loads. The topic is very interesting.

English grammar and punctuation is good and acceptable.

Major:

How can you scale the experimental model 1:20/3. What is the prototype reference? The scaling shall be discussed in more detail.

P. 2, L. 14ff needs reference(s)!

I don't exactly know the template guidelines concerning parameters. But no parameter is written slanted (cmp. e.g. Journal Hydraulic Engineering). This should be clarified with the editor. And e.g. Fig. 2: the ratios of the text do not fit with the text size. And in the Fig. parameters are written with regular font, in the caption slanted. Carefully check the entire document.

Fig 2: is the pool length really 6.1 cm???

P. 4, L. 13: MID manufacturer? Accuracy? Same question for USS probes.

Fig 4: can you explain in more detail the error up to 6 %? When I performed comparable measurements, I used USS probes with a quite small range and hence a small measurement area.

Section 2.4 needs further information. You shall provide more details on the load analyses since this is the major part of your work.

Fig 7: It seems like RANS can reproduce flow fluctuations (especially for Q2) very well. In experimental models, fluctuations can be observed also with lower frequencies (some seconds). Did you investigate or observe these effects in the numerical simulations? Check Fig. 8, Q2, d) for instance. I don't know if your statement on P. 12, L. 18 ff is enough. Please clarify.

Minor:

The Abstract starts very "rapidly". Maybe a sentence on crossbar block ramp usage can be included. "Crossbar block ramps are used to conquer… "

You shall mention the model OpenFOAM in the Abstract. Not only "two CFD models…"

3, L. 3 ff: Why did you choose exactly this geometry?

As seen in Fig. 3, the width is very limited and a 2D model results. You don't use any openings in the crossbars which majorly influences the flow. You shall give a statement in this chapter.

P. 6, L. 31ff: this is very interesting. Can you provide more details? Is it a HPC?

Fig 9 is great: did you observe and highlight LES flow phenomena in experimental model results?

P. 14, L. 1: that's absolutely correct. The question is, why didn't you measure more data in the experimental model!?

P. 15, L. 25 ff: as far as I understand, your simulations are small scaled like the experimental model. Why not using a prototype scale for CFD? This could help answering the questing on scale effects.

2.5 Authors responses to Reviewer C comments:

Comment	Addressed?	Response
1. How can you scale the experimental model 1:20/3. What is the prototype reference? The scaling shall be discussed in more detail.	Yes	The geometry has been determined according to minimum requirements for crossbar block ramps in Germany (DWA 2014 reference, P3. LL 17-18). The scale of 1:20/3 was chosen to fit in the laboratory flume; we added this information in p.3, L14. The scale is larger (better) than that of comparable of Froude-scale models (e.g. Volkart (1972) 1:30, Sindelar (2006) 1:10, Oertel (2012) 1:15. See also response to Editor comment #2.
2. P. 2, L. 14ff needs reference(s)!	No	While we did not find a reference explicitly dealing with conditions for a 2D crossbar block ramp model, we still stand by the reasoning given (most influential parameters do not change with crosswise dimension). Added "to neglect this direction and" to make it more clear. McSherry et al. (2018, 10m long, 30 cm wide) and Volkart (1972, 5,5 m long and 30 cm wide) used similar setups.
3. I don't exactly know the template guidelines concerning parameters. But no parameter is written slanted (cmp. e.g. Journal Hydraulic Engineering). This should be clarified with the editor.	Yes	Changed all variables and parameters in running text to italics (slanted), but not acronyms and abbreviations.
4. And e.g. Fig. 2: the ratios of the text do not fit with the text size.	Yes	Addressed by changing the scale of Figs. 2, 6, and 7, see Rev. A comments.
5. And in the Fig. parameters are written with regular font, in the caption slanted. Carefully check the entire document.	No	Checked the document, but kept regular type in the figures as (a) there is no surrounding text, i.e. no need for clarification between text and variable, and (b) the effort would be high for little effect.

6. Fig 2: is the pool length really 6.1 cm???	Yes	Thank you for pointing out this error. The correct pool length is 0.661 m. Addressed in Figure 2.
7. P. 4, L. 13: MID manufacturer? Accuracy? Same question for USS probes.	Yes	Added details of the flow meter and accuracy of the ultrasonic probes in the beginning of section 2.2.2.
8. Fig 4: can you explain in more detail the error up to 6 %? When I performed comparable measurements, I used USS probes with a quite small range and hence a small measurement area.	Yes	Did you compute the percentage error using the median values from fig. 8? We agree that a smaller angle and cone diameter would be preferable in hindsight, but assess the resulting imprecision as negligible for our conclusions. The strongly inclined and wavy surface is an unusual application to our knowledge. Therefore, we found it important to include a detailed analysis in the paper.
9. Section 2.4 needs further information. You shall provide more details on the load analyses since this is the major part of your work.	Yes	Restructured section 2.4 to better distinguish between accuracy and load sections in chapter 3, see also new paragraph at the beginning of chapter 3. Added insights on real crossbars vs. our model crossbars.
10. Fig 7: It seems like RANS can reproduce flow fluctuations (especially for Q2) very well. In experimental models, fluctuations can be observed also with lower frequencies (some seconds). Did you investigate or observe these effects in the numerical simulations? Check Fig. 8, Q2, d) for instance. I don't know if your statement on P. 12, L. 18 ff is enough. Please clarify.	Yes	As you point out correctly, fluctuations occur at different frequencies/periods. Fig. 8 shows that indeed we have observed such different periods, which were lowest in the physical model and LES, and larger in URANS. We changed the statement in section 3.2.2 and added a better explanation of the supposed mechanism, with reference to fig. 9.
11. The Abstract starts very "rapidly". Maybe a sentence on crossbar block ramp usage can be included. "Crossbar block ramps are used to conquer… "	Yes	Added explanatory sentence.
12. Abstract - You shall mention the model OpenFOAM in the Abstract. Not only "two CFD models…"	Yes	Mentioned the OpenFOAM toolbox in abstract.
13. 3, L. 3 ff: Why did you choose exactly this geometry?	Yes	The ecological minimal requirements were chosen to keep the physical and CFD models as small as possible. Changed "comply" to "conform to" to make this clearer. See response to Reviewer C comment #1.

14. As seen in Fig. 3, the width is very limited and a 2D model results. You don't use any openings in the crossbars which majorly influences the flow. You shall give a statement in this chapter.	Yes	We neglected the openings in the crossbars to simplify the model, foster comparability and to be able to use a quasi-2D physical model as a reference. Added a statement in section 2.1.
15. P. 6, L. 31ff: this is very interesting. Can you provide more details? Is it a HPC?	Yes	Yes, it was computed on a HPC. Added hat information. We are not really sure which other details could be interesting, e.g. the cores are clustered on nodes of 2x20 cores with 96 GB RAM each.
16. Fig 9 is great: did you observe and highlight LES flow phenomena in experimental model results?	No	Eddy structures in the basins observed in the LES model were also observed in the physical model, using small particles and dyes. Unfortunately, no objective comparison was conducted.
17. P. 14, L. 1: that's absolutely correct. The question is, why didn't you measure more data in the experimental model!?	Yes	The physical model was primarily developed for the validation of the CFD models. Added a sentence in section 2.2.1 to explain this fact. A more complex measurement of the base point moments on the crossbars was not feasible in the schedule of this work.
18. P. 15, L. 25 ff: as far as I understand, your simulations are small scaled like the experimental model. Why not using a prototype scale for CFD? This could help answering the questing on scale effects.	No	A 1:1 scaled CFD model requires more computational effort due to the larger domain and increasing number of cells, if air bubbles shall be captured. Since computational requirements were already high and scale effects were not our focus, we decided to use the same scale for both the physical and the CFD models. See response to Reviewer C comment #1 and Editor comment #1