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Effect of blocked driftwood on the hydraulic performance of a gated standard weir

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Abstract

Driftwood belongs to riverine ecosystems and is stored and transported in every natural stream. Hydraulic structures built in streams typically alter the flow characteristics and might consequently get in conflict with driftwood. The latter can get trapped at limited cross-sections and then hinders the water to pass. The upstream water level subsequently raises, since the flow needs more energy to pass the obstacle. This might lead to inundations of upstream zones or to overtopping of dams. Both are not acceptable. The herein presented study addresses this issue, focusing on a standard weir with piers (to hold gates or flaps). Such a configuration is frequently used to regulate the flow on dam spillways. We have conducted systematic model tests supplying large driftwood volumes, varying the discharge and the bay width. The reduced discharge coefficient under driftwood impact was derived, allowing to determine the related reservoir level rise. Furthermore, three technical installations, denoted as countermeasures, were tested to avoid the observed discharge capacity limitation of a jammed weir. These measures included (i) overhanging piers (protruding into the reservoir), (ii) driftwood racks installed upstream of the weir, as well as (iii) the removal of the piers generating “wide” bays. The tests indicated that, under the herein tested conditions, all measures were highly efficient. The discharge coefficient remained typically at almost the free weir flow capacity (>90%), even under a high driftwood occurrence.

Keywords: Driftwood; Standard weir; Overtopping; Reservoir level rise; Risk

1. INTRODUCTION

Natural rivers transport water, sediments and driftwood. Particularly floods might activate deadwood on flood plains, entrain fresh wood by bank erosion or collect anthropogenic wood. Large driftwood elements are part of every aquatic ecosystem, altering the local flow characteristics, bathymetry and granulometry.

In natural streams, the transport (during floods) and the deposition (between floods) of driftwood is not problematic, since the river disposes of the necessary area to adapt its characteristics. As soon as the stream approaches urbanized regions, however, driftwood might get in conflict with cross-sectional restrictions, occurring for instance at bridges, in channelized reaches or at weirs.

Weirs are frequently built in the context of hydropower production in order to assure a certain water level. Occurring driftwood might get in conflict with the weir, particularly if the weir is regulated and therefore equipped with piers. Piers represent vertical barriers and are thus prone to driftwood blockage, as many experiences on prototype prove (e.g. Palagnedra Dam Switzerland, Bruschin et al. 1981). The consequence of a driftwood blockage at a weir is a modified rating curve, resulting in comparably higher heads necessary to spill a given discharge. The reservoir level rises consequently uncontrolled, what might be critical in terms of flooding or dam safety. As soon as a weir is installed in an afforested catchment, driftwood occurrence should be considered for its design, similar to the design flood.

Several studies investigated the behavior of driftwood at weirs or spillways inlets. An overview of literature in this context is given in Bénet et al. (2021, 2022). All references indicate that a blocked structure imposes significantly higher heads, as compared to the free rating curve. A key study serving as reference for the herein presented work was published by Godtland and Tesaker (1994), who conducted model tests with driftwood on an standard weir with and without piers. They indicated that, without piers, the passage probability increased with increasing discharge. To avoid blockage, the free vertical opening between the crest and the bridge should be at least 15% of the maximum trunk length L_M, and the relative bay width should be $b/L_M \geq 0.80$, with b as bay width and L_M as the length of the largest trunk.

The “Godtland and Tesaker” criterion $b/L_M \geq 0.80$ thus refers *a priori* to the blocking probability. If the bays are sufficiently large, then driftwood should pass and hence not affect the rating curve of the weir. Most efficient is therefore the installation of “wide” bays, if possible, at new structures. On existing structures, the piers might be too close to assure driftwood passage, generating a certain risk for clogging.

Existing dams with “narrow” bays being potentially subjected to driftwood should be analyzed in terms of risk, and countermeasures reducing the reservoir level rise potential might be applied. Such measures are discussed in literature for several particular prototypes, but rarely in a general way or based on a systematical test program. Accordingly, we conducted physical model tests on a standard weir equipped with piers and an upstream reservoir to evaluate the effect of blocked driftwood on the rating curve, as well as countermeasures to handle the driftwood such that the driftwood does not significantly reduce the discharge capacity. The detailed outcomes are described in Bénet et al. (2021a, b) and Bénet et al. (2022).

The presently chosen approach was to model “extreme” scenarios with “high” discharges (up to the weir design discharge), “large“ and “determinant” driftwood volumes as well as “long” trunks combined with “narrow” bays, in order to enhance blocking and thus the reservoir rise.

2. EXPERIMENTAL SETUP

Physical model tests were performed in a straight channel at the *Platform of Hydraulic Constructions* (PL-LCH) of *Ecole Polytechnique Fédérale de Lausanne* (EPFL, Fig. 1, Bénet et al. 2021). The latter was horizontal, 10 m long, 1.500 m wide, and 0.700 m high. At its end, an (standard) ogee weir with a design (subscript *D*) head of H_D=0.150 m was inserted. Its crest was W=0.420 m above the channel bottom, so that effects of the approach flow velocity on the rating curve were small (Hager et al. 2020).

The weir was equipped with 0.040 m thick and round-nosed piers. Their upstream front either was aligned with the vertical weir front or was overhanging into the reservoir. The piers were mounted on a frame and could be moved transversally, allowing to provide 1 to 5 open bays of equal width b per configuration. The latter was varied between 0.175 m≤b≤1.500 m among the configurations. The discharge Q was supplied by the in-house pumps and measured by a magnetic inductive flowmeter (Krohne, Switzerland) up to 0.5% full-scale. A point gauge was fixed 2 m upstream of the weir crest, used to measure flow depths up to 1 mm. Note that the maximum kinematic flow head for H_D was on the order of the measurement accuracy and thus negligible. A flow tranquillizer was installed 6 m upstream of the weir to provoke homogenous approach flow conditions (Furlan 2019). The hydraulic model performance was validated, among others by comparing the measured rating curve without driftwood with the theoretical curve given in literature (Hager et al. 2020).

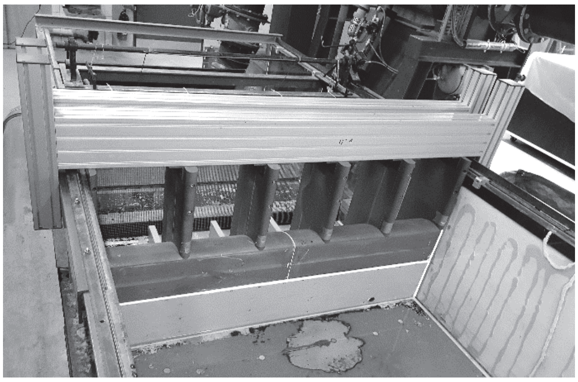
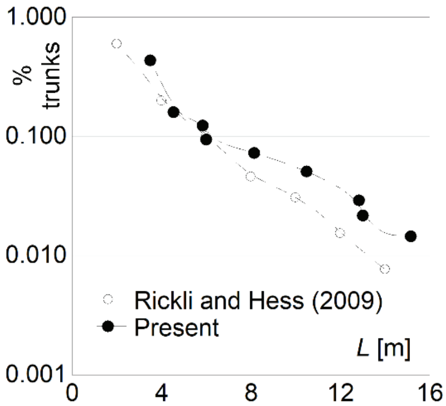


Figure 1. Photo of the physical model (channel end) with weir and piers, seen from upstream.



(a)

(b)

Figure 2. (a) Driftwood characteristics of present study and compared to in situ values, and (b) photo of driftwood classes used in the model.

The driftwood consisted of bush and tree branches and was selected in order to have quasi-natural shapes and surfaces. It was watered some hours before each test to reach an adequate humidity. The length L mixture of the trunks was defined following the *in-situ* observations of Rickli and Hess (2009), describing driftwood accumulations at weirs after floods in Switzerland. As compared to other length distributions available in literature, their curve is rather coarse. Such "large" trunks certainly tend to block more easily and are thus consistent with our intention to consider an "extreme" situation. Their trunk length distribution is shown in Fig. 2a and compared with the present mixture.

The inserted driftwood volume was rather large ("extreme"), exceeding the determinant volume as defined by Schalko et al. (2019). Note that the latter determination is not evident in our set-up, given that the boundary conditions are different from those of Schalko et al. (2019). Accordingly, we have varied the driftwood volume and defined the latter sufficiently large to avoid a significant effect on the hydraulic parameter.

The supplied driftwood volume V was composed of 2'760 trunks and 80 rootstocks. We have partially also tested smaller driftwood batches with $0.25V$ and $0.50V$. The hydraulic outcomes were not influenced thereby.

The following trunk length distribution was provided, in accordance with Fig. 2a

- L_M=0.433 m, 40 trunks, maximum (subscript M) length
- L=0.372 m, 60 trunks
- L=0.367 m, 80 trunks
- L=0.300 m, 140 trunks
- L=0.233 m, 200 trunks
- L=0.172 m, 260 trunks
- L=0.167 m, 340 trunks
- L=0.130 m, 440 trunks, and
- L=0.100 m, 1200 trunks.

Figure 2b shows a photo of the driftwood shape, surface and composition (length distribution) as used herein. As for the trunk diameter $D=L/20$ was chosen.

Furlan (2019) recommended repeating similar driftwood tests several times to assure the statistical relevance of the outcome. They observed that the number of required repetitions decreased with the number of trunks per batch. Their largest batches were composed of 32 trunks, whereas we worked with 2'760 trunks plus 80 rootstocks. Their recommendation of 10 test repetitions was thus certainly conservative for our case. Initially working with three repetitions per test, we assessed that the measured head varied less than 4%, so that most experiments were finally conducted only once.

The hydraulic parameters were defined based on the Poleni equation. The outcomes in terms of driftwood effects were analyzed with the weir discharge coefficient C_d expressed as

$$C_d = \frac{Q}{nb_e\sqrt{2gH^3}} \quad [1]$$

where Q is the discharge and n the number of open bays. The hydraulically active bay width $b_e=b-(2K_pH)$ was considered being slightly smaller than the geometrical width b, with K_p as pier parameter (Hager et al. 2020). Furthermore, g is the gravitational acceleration and H the hydraulic weir head. The parameters are visualized in Fig. 3, representing a vertical weir section.

The discharge Q was expressed non-dimensionally with the head ratio of the standard weir as

$$\chi_R = \frac{H_R}{H_D} \quad [2]$$

Note that the discharge was set in the model whereas the resulting head was measured (to derive C_d, see comment to Eq. 3), being eventually altered by the presence of driftwood. Consequently, H_R gives the reference head (for the installed discharge) without any effect of driftwood.

All geometrical and hydraulic configurations were tested with and without driftwood occurrence. The effect of the driftwood on the discharge coefficient – and thereby implicitly also on the head rise of the reservoir due to a blocked weir – was expressed with the efficiency coefficient as

$$\eta = \frac{C_d}{C_{dR}} \quad [3]$$

There, C_d follows for Eq. 1 and was derived from the measured values of H with driftwood (blocked case, large H), whereas C_{dR} gives the reference case without driftwood (Eq. 1 with H_R without driftwood). An efficiency coefficient of η=1, for instance, means that the driftwood blocked at the weir would not reduce the hydraulic capacity and the free weir rating curve applies, whereas values η<1 point at a discharge efficiency reduction combined with a head rise due to the driftwood presence.

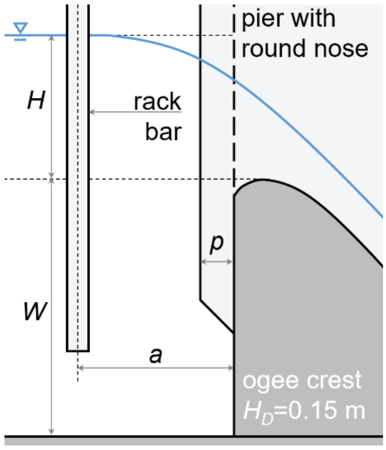


Figure 3. Parameter definition in a vertical weir section, already including some countermeasures to limit the hydraulic effect of driftwood.

The detailed test procedure as well as the full test program are given in Bénet et al. (2021). The following parameters were systematically varied in the model

- Discharges within 0.005 $m^3/s \leq Q \leq 0.171$ m^3/s, corresponding to $0.098 \leq \chi_R \leq 1.029$. Typically, values of χ_R=0.33, 0.67 and 1 were tested so that reference heads (reference discharges) attained H_R=0.05, 0.10 and 0.15 m. Again, the discharge was set to the values that would occur without driftwood, and the resulting H under the influence of the driftwood (being different for the reference H_R) was measured.
- Model bay widths within 0.175 m≤b≤1.500 m ($0.40 \leq b/L_M \leq 3.46$), with a number of open bays between n=1 and 5. Typically, relative bay widths – normalized with the maximum trunk length (herein L_M=0.433 m) as suggested by Godtland and Tesaker (1994) – of b/L_M=0.40, 0.60, and 0.77 were tested. The case of n=1 corresponded to the absence of piers, and thus to a measure to limit the effect of driftwood on the hydraulic capacity.
- A pier front overhang p=0 m stands for aligned piers (Fig. 3), whereas an overhang of p=0.04 m and 0.08 m represent a measure to limit the effect of the driftwood on the hydraulic capacity. Aligned piers were tested first.
- Finally, a configuration without rack was tested first, and subsequently two rack types were mounted at a distance a upstream of the vertical weir front as a measure to limit the effect of driftwood on the weir rating curve.

3. RESULTS WITHOUT COUNTERMEASURES

The configuration referred to herein includes the weir with aligned (p=0 m) piers and no rack, and comprises 33 model tests. They shall represent a worst-case scenario: An extreme flood (up to the design discharge with χ_R=1) transporting an extreme driftwood volume with comparatively long trunks hits the weir. The bays are relatively narrow (down to b/L_M=0.40), so that a severe blockage of driftwood might be expected (Godtland and Tesaker 1994), accompanied by a considerable reservoir level rise.

As expected, all the driftwood blocked at the weir. Only very few trunks passed (and were brought back into the model). Figure 4 gives an impression of the model weir with the blocked driftwood, seen from upstream. The appearance in the model resembles strongly that of similar cases known from prototypes (Bruschin et al. 1981).

The model heads H with blocked driftwood were measured and compared to the reference heads H_R without driftwood. A direct comparison yet without normalization (i.e., in model dimensions) is shown in Fig. 5a as a function of the unit discharge q, the driftwood volume V, and the relative bay width b/L_M. The measured heads with driftwood (symbols) systematically exceed those without (line), particularly for larger discharges. Instead of a reference model head of H_D=0.15 m for the design discharge q_D and without driftwood, the latter generated heads between roughly H=0.17 to 0.19 m if blocked.

Figure 4. Photo of the driftwood blocked at the model weir, for the set-up without countermeasures (χ_R=1, b/L_M=0.77, V).

Figure 5b shows the same data as Fig. 5a (with the same legend), but now expressed non-dimensionally. The head was normalized as discharge coefficient following Eq. (1) and the discharge as head rate with Eq. (2). The plot includes both, the driftwood tests as symbols and the reference tests for free weir flow (line). The presence of driftwood reduced the discharge capacity under a creation head (or – *vice versa* – raised the reservoir level for a certain discharge, Fig. 5a), so that the C_d values systematically decreased. The discharge coefficients were particularly lessened for maximum tested discharges, being problematic in terms of flood release at spillways.

The discharge coefficient of a blocked weir differed from the prediction of literature (e.g., Hager et al. 2020) for a free weir flow. Instead of increasing slightly with the discharge (line in Fig. 5b) it remained constant at around C_d=0.4. Statistically spoken, the mean of all related tests with driftwood was $C_{d\mu}$=0.38, with a standard deviation of σ=0.02. If subtracting the standard deviation from the mean, then C_d=0.36 results, a value serving to reasonably predict the remaining discharge coefficient or the reservoir level rise for blocked standard weirs without countermeasures.

Note that the latter did quasi not depend on the bay width (if b/L_M<0.80, Godtland and Tesaker 1994), the discharge (up to the design discharge), and the driftwood volume supplied (as long as the latter is above the determinant volume, Schalko et al. 2019). Furthermore, the reservoir configuration (upstream of the weir) generated relatively small flow velocities in the area where the wood was blocked. Particularly elements positioned distant form the weir were subjected to negligible hydrodynamic forces. Consequently, the driftwood appeared relatively loose and floated on the water surface in only few vertical layers (mostly 1 to 3D), even at the weir.

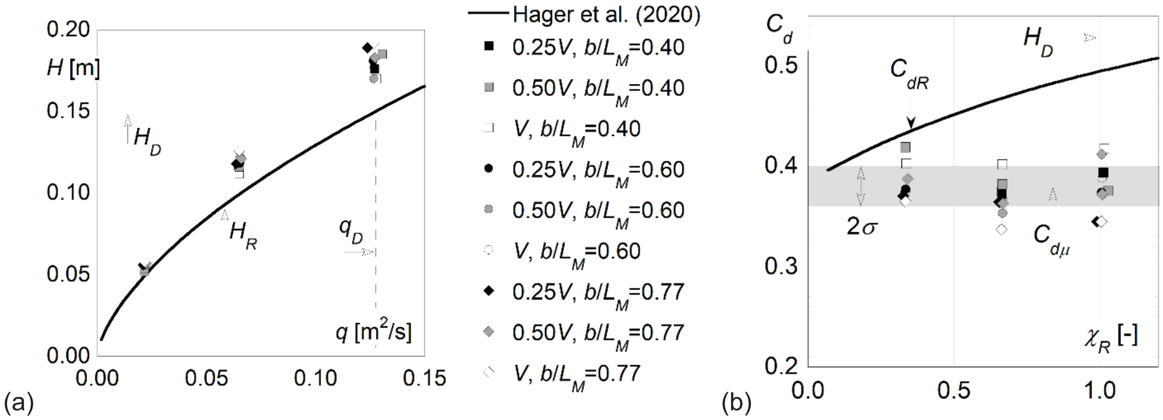


Figure 5. Effect of driftwood (without measures at the weir, for the herein tested configurations), (a) head H versus unit discharge q, and (b) discharge coefficient C_d (Eq. 1) versus head ratio χ (Eq. 2).

4. COUNTERMEASURES

Driftwood blocked at a weir with piers (generating narrow bays, b/L_M<0.80) affects its rating curve. The driftwood is close to the critical flow section and disturbs the latter (Bénet et al. 2021b), so that a free weir flow cannot establish. If the effect of driftwood shall be lowered, then the wood has to be distant from the critical section and thus far from the weir crest. The driftwood should then be retained “further” upstream of the weir crest as compared to the weir without measures, or pass the crest. The hereafter presented and model-tested countermeasures provoke both effects: overhanging piers protruding into the reservoir and a rack mounted in front of the weir keep the driftwood distant from the weir crest, and the removal of piers enables the passage of driftwood for larger discharges.

4.1. Pier overhang

Piers protruding into the reservoir may not only affect the hydraulically active bay width b_e but will also keep the driftwood distant from the weir crest. The effect of the pier overhang p (Fig. 3) was investigated in the model with 35 additional tests (χ_R=0.33, 0.67 and 1; b/L_M=0.40 and 0.77; 0.25V, 0.50V and V), including a prolongation of the model pier nose from p=0 m (pier front aligned with the weir front, Fig. 6a) to 0.04 m (Fig. 6b) and 0.08 m (Fig. 6c). As visible in Fig. 6, the driftwood was blocked further away from the weir crest (the latter was located roughly below the vertical front of the transversal support frame) with increasing pier overhang. The critical flow section was then less influenced by the presence of the driftwood (Bénet et al. 2021b) and the open flow section approaching the weir became larger, i.e., the flow could better pass between the floating driftwood and the weir front.


(a)
(b)
(c)

Figure 6. Driftwood blocked at overhanging piers, with (a) p=0 m, (b) p=0.04 m, and (c) p=0.08 m (χ_R=1, b/L_M=0.77, V).

The pier overhang had a positive effect on the weir discharge coefficient. Longer overhangs generated larger coefficients, reaching ultimately quasi-free flow conditions. Hydraulically, the distance between the critical flow section (near the weir crest) and the most downstream driftwood front (touching the pier front) seems determinant (Bénet et al. 2021b). Herein, we normalized the overhang p with the reference head H_R to express the relative pier overhang. The latter was used to indicate the efficiency coefficient η following Eq. (3) for the various tested set-ups. As visible in Fig. 7, a relative overhang of roughly p/H_R>0.35 generated η>0.90 for all herein tested configurations. A considerable reduction of the discharge capacity (to less than 90% of the free weir discharge coefficient) might accordingly be avoided if the pier front protrudes by p>0.35H_D into the reservoir, with the (maximum) design discharge head as reference. For lower discharges, the relative overhang increases (for the given p), so that the situation is less critical.

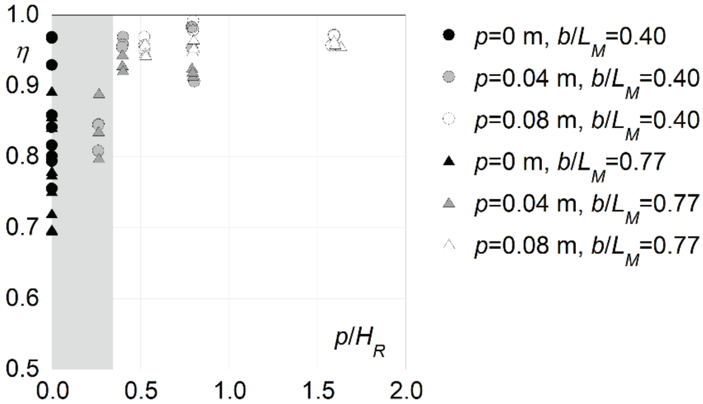


Figure 7. Efficiency coefficient η for overhanging piers in function of the relive overhang p/H_R.

4.2. Driftwood rack

Similar to overhanging piers, a rack installed in front of the weir retains the driftwood at a certain distance upstream, and accordingly also distant from the critical flow section. We have conducted several model tests with two rack configurations installed at various positions (30 supplementary tests by Bénet et al 2021a, and 35 supplementary tests by Bénet et al. 2022). Relative bay widths of b/L_M=0.40, 0.60 and 0.77 were tested, the pier overhang was p=0 m, and relative heads between χ_R=0.17 and 1.02 were provided. The supplied driftwood volume was again 0.25V 0.50V and V.

Two rack configurations were installed: the full and the partial rack. A full rack had a rack bar in front of each pier (Fig. 8a), whereas the partial rack only had a bar at every second pier (Fig. 8b). The transversal bar spacing was therefore either b (full rack) or 2b (partial rack). The bars were circular and had a diameter of 0.04 m (similar to the pier thickness), were aligned with the pier and positioned at a streamwise distance of a≥0.5b (Fig. 3) upstream of the vertical weir front.

Figure 8 shows that the driftwood blocked at the racks. For a full rack (Fig. 8a), the wood front was quite linear because of the numerous bars. In contrast, the driftwood front undulated at the partial rack between the few rack bars and the intermediate piers (Fig. 8b). Nevertheless, both rack geometries removed most driftwood from the weir front, so that the flow was only slightly affected.

(a)  (b) 

Figure 8. Driftwood blocked at (a) full and (b) partial rack (χ_R=1, b/L_M=0.77, V, a=0.5b).

This observation is confirmed in Fig. 9, showing the efficiency coefficient η (Eq. 3) versus the relative rack position a/H_R (Fig. 3). The figure includes data of both rack configurations (full and partial), data of the context without measure (adapted from Fig. 4b), as well as the data form the overhanging piers. For the latter, p=a was set. As mentioned in the context of pier overhang, also racks maintain a high efficiency coefficient if positioned adequately. A relative position between roughly 0.35<a/H_R<4 generated again η>0.90 for all herein tested configurations. Considering only the racks (and ignoring the pier overhang), then even η>0.95 was achieved within these limits. If the rack was closer, then the driftwood interacted with the critical section and η dropped. *Vice versa*, a rack position far away from the weir front allowed some trunks to lean against the intermediate piers, so that η again reduced. This phenomenon was slightly more pronounced for partial than for full racks. Racks are therefore most efficient to maintain a high discharge capacity at weirs affected by driftwood. The rack spacing seems less important, whereas its streamwise position a/H_R should be adequate.

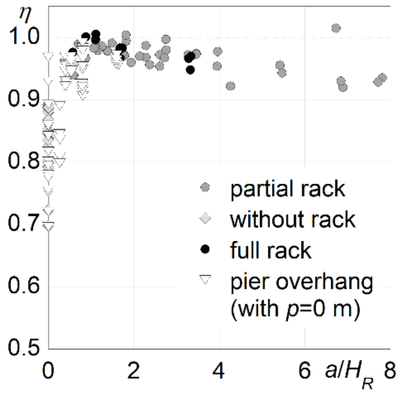


Figure 9. Efficiency coefficient η for full and partial racks (and overhanging piers with $p=a$) in function of the relative position a/H_R.

4.3. Absence of piers

The two measures introduced before both retain the driftwood upstream of the weir, so that it might not interfere with the critical flow section. Consequently, the efficiency coefficient remains high, what is the goal of such measures. From an ecological point of view, the full driftwood retention is inappropriate, since the wood is then lacking as ecological element of the stream downstream of the weir.

The most elegant approach to maintain driftwood within the stream and to avoid any additional reservoir level raise at a weir is to provoke its passage. To achieve this, all obstacles at which driftwood might get jammed have to be removed. Piers typically represent such obstacles. The driftwood could alternatively be partially oriented and then rather pass between the piers (Bénet et al. 2022). This alternative is unfortunately less efficient in terms of blockage as well as level rise. We have focused herein on the removal of the piers.

The model was hence operated without piers (Fig. 10) for 19 additional tests. Then, b/L_M=3.46 resulted, being much above the Godtland and Tesaker criterion, and the driftwood consequently past as soon as the flow momentum was sufficient. Driftwood volumes of 0.25V, 0.5V and V were tested, and (small) head ratios up to χ_R=0.38. For larger discharges (head ratios), the driftwood passed the weir systematically, so that the tests were stopped. Figure 10a shows such a case with a flow momentum inducing sporadic driftwood passage.

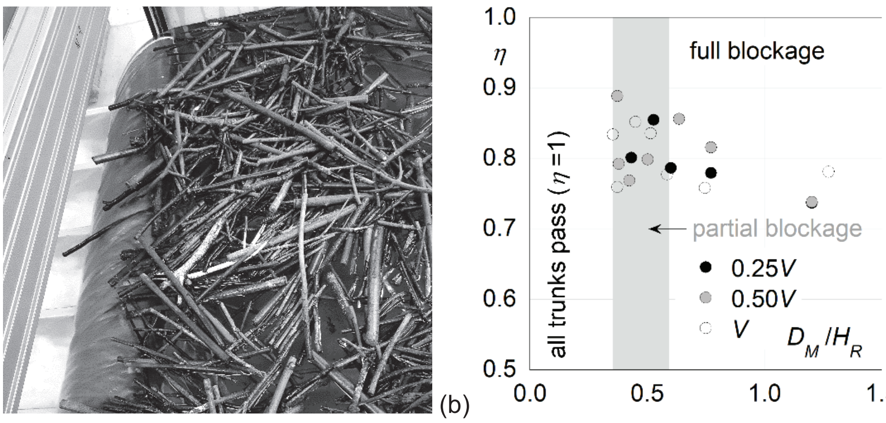
(a)  (b)

Figure 10. (a) Photo of model without piers and frequent driftwood passage, and (b) efficiency coefficient η versus the relative trunk diameter D_M/H_R.

For “very small” discharges, the entire driftwood volume blocked at the weir, for “small” discharges frequent passage occurred, and for “medium” discharges, the passage appeared systematically. The efficiency coefficient η was thus visualized in function of the relative trunk diameter D_M/H_R (Fig. 10b). The diameter of the largest trunk was taken as reference (D_M=0.022 m herein), given that it generated the blocking. Three regimes were observed: (1) full blockage for D_M/H_R>0.60 with η between 0.75 and 0.85, (2) individual trunk passage for 0.35≤D_M/H_R≤0.60 with η between 0.75 and 0.90, and (3) a free weir without blockage for D_M/H_R<0.35 with η near 1. Pfister et al. (2013) indicated similar limits of D_M/H_R>1 for full blockage and of D_M/H_R<0.35 for full passage.

The removal of piers (the creation of wide bays) is most efficient to overcome difficulties with driftwood. At the Palagnedra Dam (mentioned in the introduction), with an uncontrolled weir, the piers were removed (Fig. 11). The removed weir bridge was replaced by a new bridge spanning between the abutments of the arched dam.

Figure 11. Photo spillway inlet (standard weir) of the Palagnedra Dam in Switzerland with the removed piers.

5. CONCLUSIONS

Driftwood is essential for sound streams but potentially a thread for hydraulic structures. There, it might generate jamming, so that the flow capacity drops and the upstream water level raises. This is potentially dangerous during extreme floods at dams, when spillways should remain fully operational. The conflict between spillway capacity and driftwood was addressed herein with physical model tests considering a gated standard weir (Bénet et al. 2021a), frequently used as spillways inlet. The study showed that the driftwood should essentially not disturb the critical flow section near the weir crest. If the latter remains free, then it can determine the rating curve.

If no measures are taken at a weir with relatively narrow bays (b/L_M<0.80, Godtland and Tesaker 1994), then the driftwood will mostly block directly at the pier front (usually identically with the weir front) under an extreme wood occurrence. The hydraulic weir efficiency drops, a phenomenon that was quantified herein by means of the weir discharge coefficient C_d. The latter remains at a low (and quite constant) value of around C_d=0.36 for a blocked weir, instead of reaching roughly C_d=0.50 for free weir flow at the design discharge (Hager et al. 2020). The “reduced” C_d value might be used to derive the required head H for a full driftwood blockage, giving thus the reservoir level rise (Eq. 1).

Three countermeasures were investigated and presented herein, intending either to block the driftwood sufficiently distant upstream of the weir (to keep free the critical flow section), or to rapidly transit it without blockage. First, overhanging piers (protruding into the reservoir) were tested. If was found that this was an efficient measure, given that the overhang exceeds 35% of the maximum flow head. Then, the hydraulic capacity (efficiency coefficient, Eq. 3) remind typically above 90%. Second, two types of driftwood racks were tested. Both were very efficient. If correctly spaced (rack bar spacing not much larger than the longest trunks) and positioned (at a distance between 35% and 400% of the flow head), then the hydraulic efficiency typically remained above 95%. Finally, a set-up without piers was investigated. The driftwood then blocked fully or partially at the weir as long as the flow head remained below some 35% of the maximum trunk diameter. *Vice versa*: As soon as the flow head exceeded some three trunk diameters, then all driftwood transited the weir and a quasi-free weir rating curve was maintained.

These results indicate that new weirs subjected to driftwood appearance should best have wide bays (b/L_M>>0.80) to avoid driftwood blockage and reservoir level rise. Existing weirs subjected to driftwood might profit from the installation of the herein proposed countermeasures. However, the jammed driftwood has then mechanically to be removed after a flood event, and should ideally be given back to the stream in the downstream reach.

6. ACKNOWLEDGEMENTS

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