

Discussion of “New Empirical Model for Breaching of Earth-Rock Dams” by

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Abstract

In this discussion, the authors will point out that even if Zhong et al. (2020) tackle an important problem, by ensuring the quality and credibility of the data recorded in the database presented and by providing the description of the used method to obtain their non-linear equations it certainly can improve their original study. Therefore, this discussion highlights the limitations and shortcoming to the study presented by Zhong et al. (2020) original paper.

1 Introduction

Overall, in the original paper, Zhong et al. (2020) have combined seven databases in order to obtain a worldwide database allowing them to deduce new empirical equations adapted for embankment dam failures. Thus, even if the authors mentioned that “the advantage of this new model is that the formulas have been developed based on a larger database of dam breach

22 cases and the choice of the input parameters. The model performance and comparison with the
23 existing empirical models testify to the rationality of the new model”, this discussion
24 demonstrates that in fact the model is not undoubtedly accurate.

25 Also, even if the authors considered that “the comparison cannot judge which model is better
26 based on these dam breach cases—the intention is only to demonstrate that relatively large
27 differences still exist in empirical dam breach models.”, this discussion highlights a fundamental
28 question which is: how much data is necessary to ensure that these dam breach cases could be
29 neglected in this judgment?

30 **2 Data quality and reliability validation**

31 Zhong et al. (2020) used a database recording mostly Chinese dam failures. Indeed, a total of
32 84 case studies from China are recorded from the 162 data recorded (i.e. 52% of the
33 compilation). After reviewing the 162 dam failures recorded by Zhong et al. (2020) it has been
34 possible to highlight that 8 references listed are not properly cited (i.e. see case studies “id” in
35 the original database of Zhong et al. (2020) : 97, 100, 104,105, 112, 138, 139 and 140) and
36 various cases have nor been properly recorded (e.g. see case studies “id” in the original record
37 : 22, 35, 50, 59, 75, 88, 91. 96, 103, 106, 107, 114, 116, 130, 136, 137, 161). Indeed, the major
38 concern is the apparent absence of any auditing of data quality in the new dataset. In fact, notice
39 that based on Zhong et al. (2020) compilation:

- 40 • The database recorded by Froehlich (2016) is not used in this compilation, even if it is the
41 most used in practice. Also, the latest database now available (Bernard-Garcia and
42 Mahdi, 2020) is also not listed in the original paper. This up-to-date database records a
43 total of 3,851 dam failures case studies.

- A total of 5 case studies are recorded as man-made dam failure, but as recorded in the references cited 2 case studies refers to natural dam failures (i.e. see case studies id in the original database of Zhong et al. (2020) : 95, 140) and 3 case studies to laboratory test data (i.e. see case studies id in the original database of Zhong et al. (2020) : 41, 66, 95).
- One key breach parameter included in the new dataset is the peak discharge. However, there are a range of methods that are used to estimate this parameter yet there is no indication in the new dataset how it has been estimated in each case.
- The second key breach parameter included in this new dataset is the time failure which in the literature has various definitions, but no distinction or correction has been considered by the authors.

3 Identification of the used method for regression analysis

Zhong et al. (2020) didn't take the effect of the failure mode in their analysis. Since some of the dam breach parameters, such as the final breach form or its time of formation, are strongly related to the breach modes, the coefficients of the empirical proposed formula and its rationality should be discussed by the authors. Moreover, a distinction between the overtopping and seepage dam failure case studies will certainly lead to more representative equations and might improve the quality of the analysis proposed by the authors. Also, Zhong et al. (2020) should have used nondimensionalized equations to reduce the number of involved parameters and increase understanding of the problem (Singh and Quiroga, 1988).

Even though, in order to identify the method used by the authors, the regression analyzes proposed in this discussion follow the author's point of view. Thereby, knowing that the formulation of the three non-linear equations proposed by Zhong et al. (2020), i.e. equations 1

67 to 3 of the original paper, can be linearly resolved in order to deduce the exact solution of the
 68 system of equations, the discussers here assumed that this simple regression method was
 69 chosen by the authors, as presented below.

70 **Non-linear equation form:**

$$71 \quad y_i = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{b_1} \cdot \left(\frac{h_w}{h_b} \right)^{b_2} \cdot h_d^{b_3} \cdot e^{b_4} \quad \text{where} \quad y_i = \begin{cases} y_1 = \frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} \\ y_2 = \frac{B_{ave}}{H_b} \\ y_3 = T_f \end{cases}$$

72 **Linear equation form :**

$$73 \quad \log(y_i) = \mathbf{b}_1 \cdot \log\left(\frac{V_w^{\frac{1}{3}}}{h_w}\right) + \mathbf{b}_2 \cdot \log\left(\frac{h_w}{h_b}\right) + \mathbf{b}_3 \cdot \log(h_d) + \mathbf{b}_4 \cdot \log(e)$$

$$74 \quad \text{where } \mathbf{b}_0 = b_4 \cdot \log(e)$$

75 The results obtained to identify the regression method used are presented in Figures 1 to 3.
 76 Thus, it is possible to highlight the non-consistency between the calibration coefficient obtained
 77 and compared to those presented by Zhong et al. (2020). Also, as illustrated in Figure 1 at least
 78 two cases have not been used by the authors, e.g. the two cases out of the domain obtained for
 79 the peak discharge equation. Therefore, explicitly specify how the calibration was obtained and
 80 the different hypotheses considered, in particular in the selection of the failure cases used, will
 81 help identify the limitations of the proposed equations.

82 **4 Calibration of the equation using the new database currently available**

83 In the same perspective, the form of the equations has been calibrated using the new database
 84 currently available in the literature (Bernard-Garcia and Mahdi, 2020). Figures 4 to 6 compare

85 the results presented by Zhong et al. (2020) to those obtained using Bernard-Garcia and Mahdi
86 (2020) database. Notice that these results were all obtained using the regression analysis tool
87 available in the XLSTAT (Addinsoft, 2020). As illustrated in Figures 4 to 6, adding new case
88 studies in fact impact the reliability of the equation obtained. Indeed, even if the results can
89 seems “similar”/“coherent” regarding the differences in the regression equation obtained and the
90 disparities identified, i.e. notably for the time failure parameter, it is beneficial for the readers to
91 clarify and justify the domain of application of their study and correctness of their hypothesis.

92 Thus, it highlights the impact and the necessity of considering the case studies used during the
93 regression analysis to ensure the quality and credibility of the predictive equation proposed.
94 Moreover, as illustrated in Figure 7, the number of case studies certainly influence the regression
95 equation obtained and it is still not possible to neglect the number and/or quality of the case
96 studies records in this empirical process which contradict what was suggested by Zhong et al.
97 (2020), i.e. “the comparison cannot judge which model is better based on these dam breach
98 cases—the intention is only to demonstrate that relatively large differences still exist in empirical
99 dam breach models”.

100 **5 Conclusion**

101 The results presented in this discussion highlight that in fact the credibility of the recorded data,
102 as well as the number of cases studies, impacts the results and needed to be first considered in
103 order to ensure the reliability of the presented equations by Zhong et al. (2020). Indeed, the
104 unreliability of the information recorded in their database, also as the incomplete references cited
105 and used to combine the previous databases in their work have certainly limited the rationality
106 of the new equations developed by Zhong et al. (2020). Overall, the shortcomings and questions

107 highlighted about the correctness of the interpretation/analysis of the data needs to be clarified
108 by Zhong et al. (2020) to provide an accurate portrait of their study.

109 **ACKNOWLEDGMENTS**

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113 manuscript.

114 **References**

- 115 Addinsoft (2020) XLSTAT statistical and data analysis solution. Paris, France.
116 <https://www.xlstat.com>.
- 117 Bernard-Garcia M, Mahdi T (2020) A Worldwide Historical Dam Failure's Database. Scholars
118 Portal Dataverse, V1. <https://doi.org/10.5683/SP2/E7Z09B>.
- 119 Froehlich D C (2016) Predicting peak discharge from gradually breached embankment dam. J.
120 Hydrol. Eng. 21 (11): 04016041. [https://doi.org/10.1061/\(ASCE\)HE.1943-5584.0001424](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001424).
- 121 Singh V P, Quiroga C A (1988) Dimensionless analytical solutions for dambreach erosion.
122 Journal of Hydraulic Research, 26:2, 179-197, DOI: 10.1080/00221688809499224.
- 123 Zhong et al (2020) New Empirical Model for Breaching of Earth-Rock Dams. Nat. Hazards Rev.,
124 2020, 21(2): 06020002. DOI: 10.1061/(ASCE)NH.1527-6996.0000374.

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Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.58} \cdot \left(\frac{h_w}{h_b} \right)^{-0.76} \cdot h_d^{0.1} \cdot e^{-4.55}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.51} \cdot \left(\frac{h_w}{h_b} \right)^{-1.09} \cdot h_d^{-0.12} \cdot e^{-3.61}$$

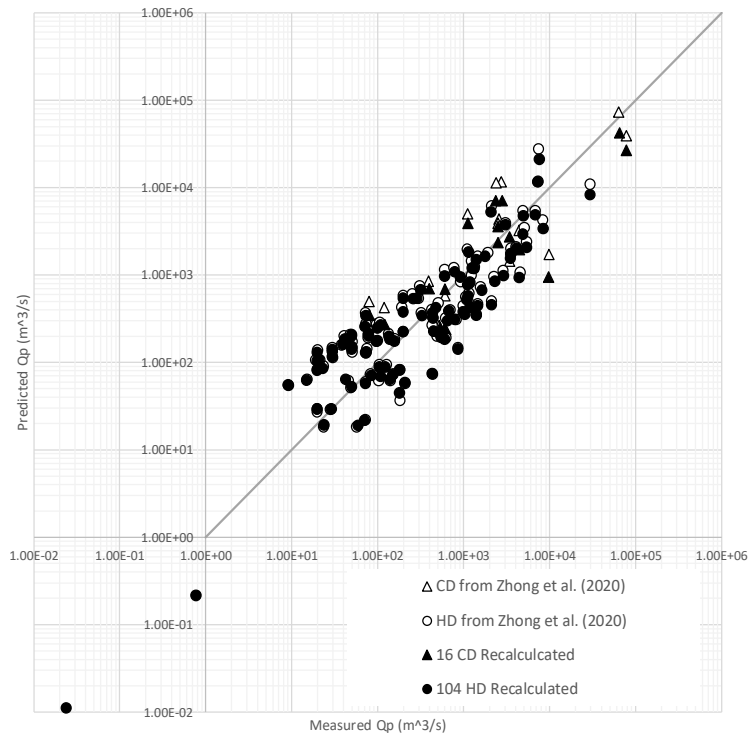
Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.64} \cdot \left(\frac{h_w}{h_b} \right)^{-1.24} \cdot h_d^{-0.001} \cdot e^{-4.24}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.37} \cdot \left(\frac{h_w}{h_b} \right)^{-5.68} \cdot h_d^{-0.68} \cdot e^{-2.46}$$



Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.84} \cdot \left(\frac{h_w}{h_b} \right)^{2.3} \cdot h_d^{0.06} \cdot e^{-0.9}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.55} \cdot \left(\frac{h_w}{h_b} \right)^{1.97} \cdot h_d^{-0.07} \cdot e^{-0.09}$$

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.77} \cdot \left(\frac{h_w}{h_b} \right)^{2.01} \cdot h_d^{0.14} \cdot e^{-0.94}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.67} \cdot \left(\frac{h_w}{h_b} \right)^{1.66} \cdot h_d^{-0.08} \cdot e^{-0.12}$$

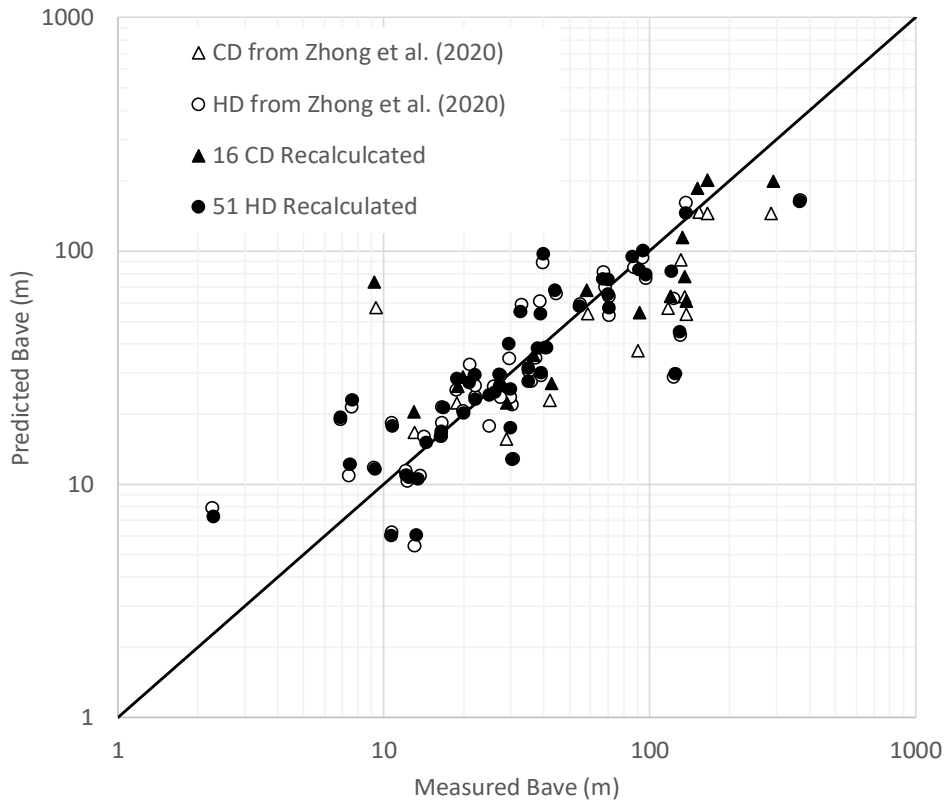


Figure 2 : Comparison of measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Zhong et al. (2020) database.

Adapted from Zhong et al. (2020) original paper

Homogeneous dams (HD) :

$$T_f = \left(\frac{1}{\frac{V_w^3}{h_w}} \right)^{0.56} \cdot \left(\frac{h_w}{h_b} \right)^{-0.85} \cdot h_d^{-0.32} \cdot e^{-0.2}$$

Corewall dams (CD) :

$$T_f = \left(\frac{1}{\frac{V_w^3}{h_w}} \right)^{1.52} \cdot \left(\frac{h_w}{h_b} \right)^{-11.36} \cdot h_d^{-0.43} \cdot e^{-1.57}$$

Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$T_f = \left(\frac{1}{\frac{V_w^3}{h_w}} \right)^{0.56} \cdot \left(\frac{h_w}{h_b} \right)^{-0.61} \cdot h_d^{-0.5} \cdot e^{0.31}$$

Corewall dams (CD) :

$$T_f = \left(\frac{1}{\frac{V_w^3}{h_w}} \right)^{1.82} \cdot \left(\frac{h_w}{h_b} \right)^{-7.05} \cdot h_d^{-0.1} \cdot e^{-3.53}$$

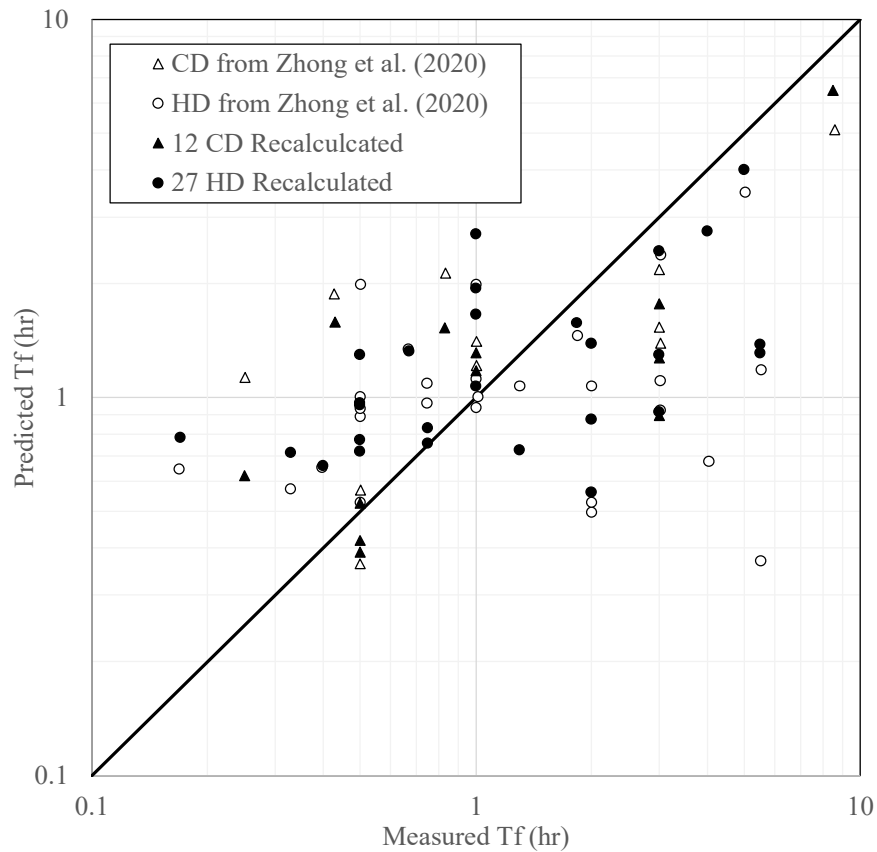


Figure 3 : Comparison of measured and predicted Time failure (Tf) for breached earth-rock dam adapted from Zhong et al. (2020) database.

Recalculated from Zhong et al. (2020) database
Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.64} \cdot \left(\frac{h_w}{h_b} \right)^{-1.24} \cdot h_d^{-0.001} \cdot e^{-4.24}$$

Corewall dams (CD) :

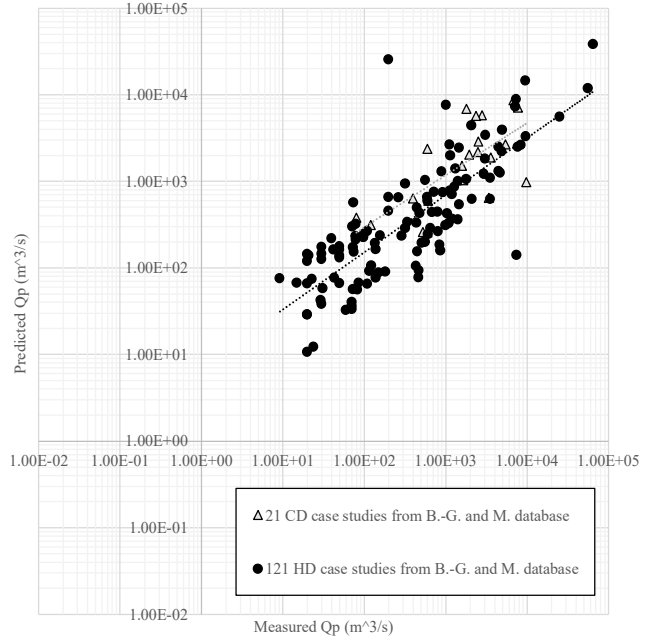
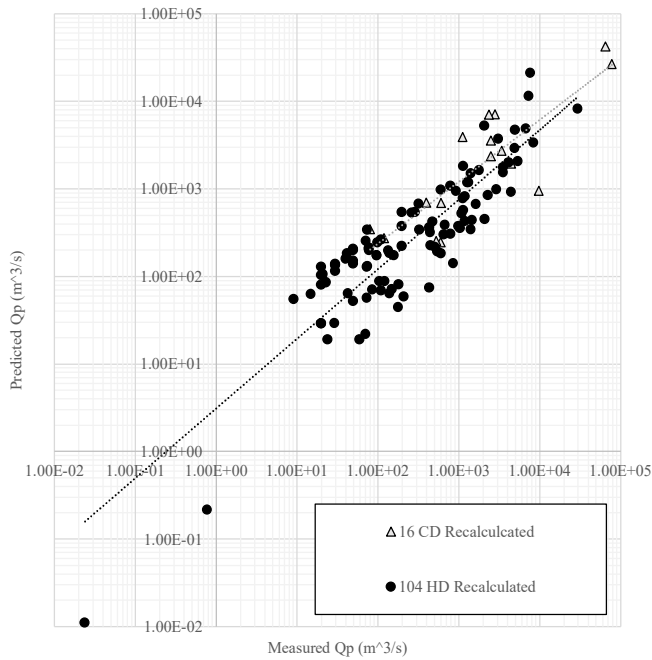
$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.37} \cdot \left(\frac{h_w}{h_b} \right)^{-5.68} \cdot h_d^{-0.68} \cdot e^{-2.46}$$

Equations adapted from Bernard-Garcia and Mahdi (2020) database
Homogeneous dams (HD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.84} \cdot \left(\frac{h_w}{h_b} \right)^{-0.4} \cdot h_d^{-0.4} \cdot e^{-2.35}$$

Corewall dams (CD) :

$$\frac{Q_p}{V_w \cdot g^{\frac{1}{2}} \cdot h_w^{-\frac{1}{2}}} = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{-1.4} \cdot \left(\frac{h_w}{h_b} \right)^{-5.35} \cdot h_d^{-0.71} \cdot e^{-2.65}$$



149

150 Figure 4 : Comparison of measured and predicted Peak discharge (Qp) for breached earthrock
151 dams adapted from Bernard-Garcia and Mahdi (2020) database

Recalculated from Zhong et al. (2020) database
Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.77} \cdot \left(\frac{h_w}{h_b} \right)^{-2.01} \cdot h_d^{0.14} \cdot e^{-0.94}$$

Corewall dams (CD) :

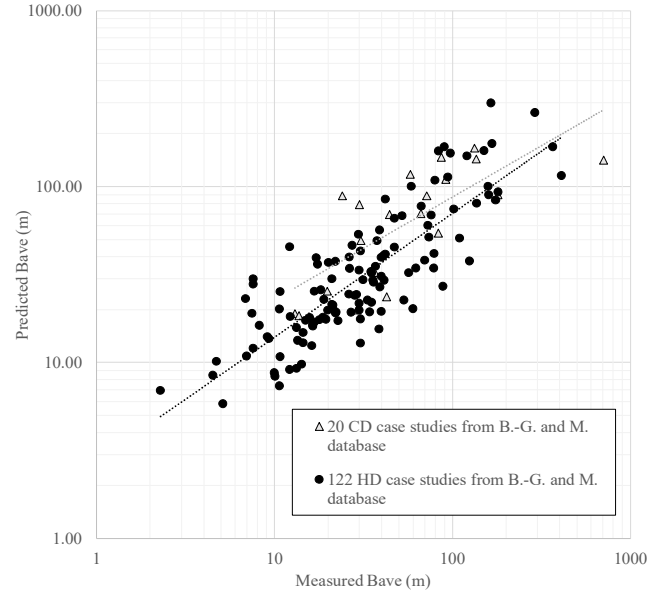
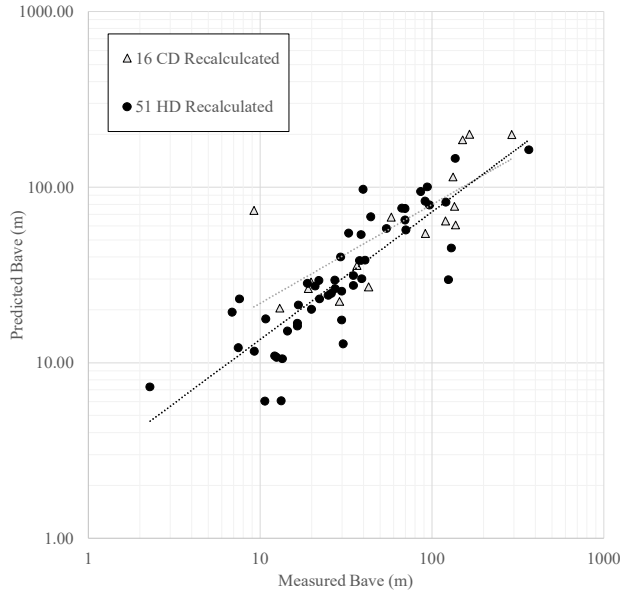
$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{-0.67} \cdot \left(\frac{h_w}{h_b} \right)^{1.66} \cdot h_d^{-0.08} \cdot e^{-0.12}$$

Equations adapted from Bernard-Garcia and Mahdi (2020) database
Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.75} \cdot \left(\frac{h_w}{h_b} \right)^{1.13} \cdot h_d^{0.22} \cdot e^{-1.07}$$

Corewall dams (CD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.95} \cdot \left(\frac{h_w}{h_b} \right)^{0.9} \cdot h_d^{0.21} \cdot e^{-1.52}$$



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Figure 5 : Comparison of measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Bernard-Garcia and Mahdi (2020) database.

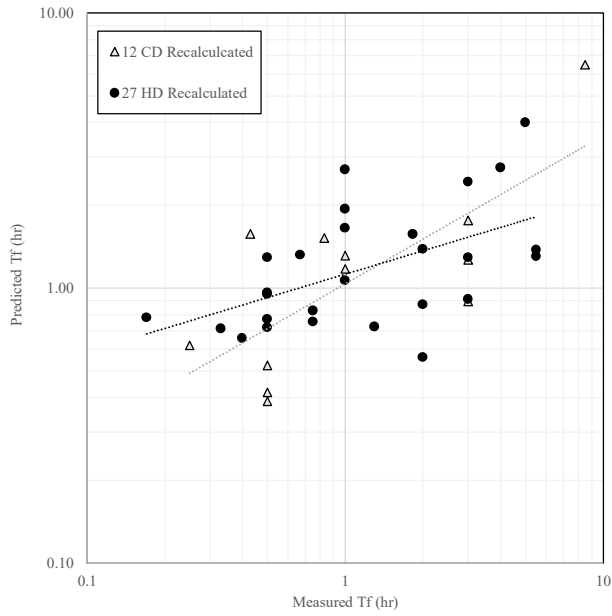
Recalculated from Zhong et al. (2020) database

Homogeneous dams (HD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.56} \cdot \left(\frac{h_w}{h_b} \right)^{-0.61} \cdot h_d^{-0.5} \cdot e^{0.31}$$

Corewall dams (CD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{1.82} \cdot \left(\frac{h_w}{h_b} \right)^{-7.05} \cdot h_d^{-0.1} \cdot e^{-3.53}$$



Equations adapted from Bernard-Garcia and Mahdi (2020) database

Homogeneous dams (HD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.87} \cdot \left(\frac{h_w}{h_b} \right)^{0.74} \cdot h_d^{0.51} \cdot e^{-3.9}$$

Corewall dams (CD) :

$$T_f = \left(\frac{V_w^{\frac{1}{3}}}{h_w} \right)^{0.29} \cdot \left(\frac{h_w}{h_b} \right)^{2.13} \cdot h_d^{-0.15} \cdot e^{-0.23}$$

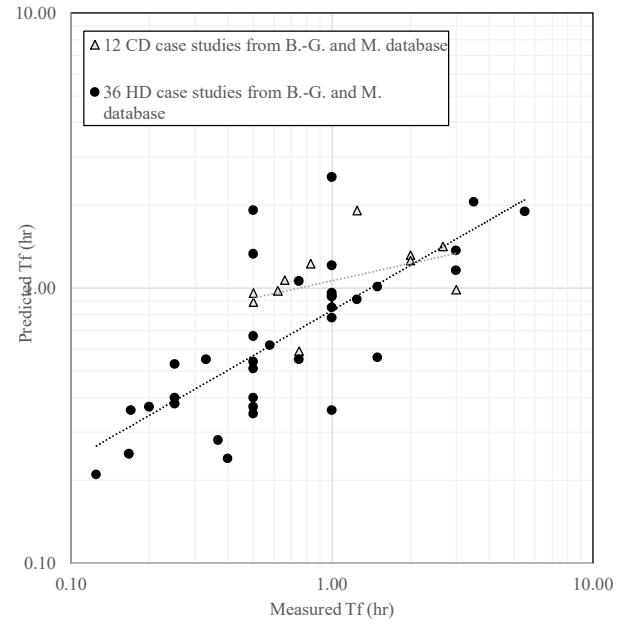
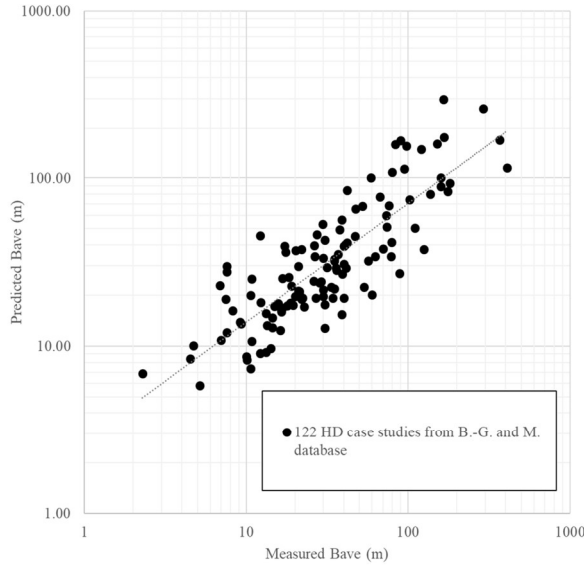


Figure 6 : Comparison of measured and predicted Time failure (Tf) for breached earth-rock dam adapted from Bernard-Garcia and Mahdi (2020) database.

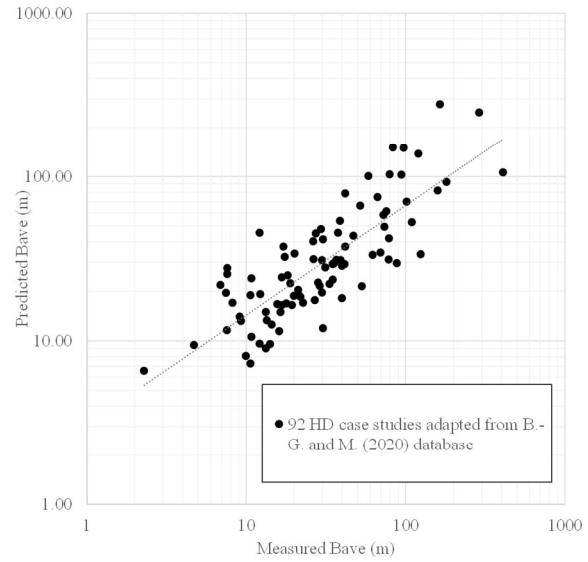
Equations adapted from Bernard-Garcia and Mahdi (2020) database
122 Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.75} \cdot \left(\frac{h_w}{h_b} \right)^{1.12} \cdot h_d^{0.22} \cdot e^{-1.07}$$



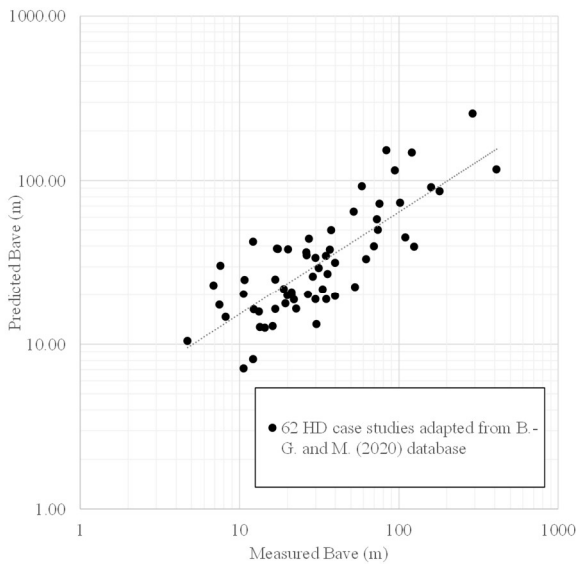
Equations adapted from Bernard-Garcia and Mahdi (2020) database
92 Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.79} \cdot \left(\frac{h_w}{h_b} \right)^{1.04} \cdot h_d^{0.19} \cdot e^{-1.15}$$



Equations adapted from Bernard-Garcia and Mahdi (2020) database
62 Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.70} \cdot \left(\frac{h_w}{h_b} \right)^{1.21} \cdot h_d^{0.23} \cdot e^{-0.98}$$



Equations adapted from Bernard-Garcia and Mahdi (2020) database
32 Homogeneous dams (HD) :

$$\frac{B_{ave}}{H_b} = \left(\frac{V_w^3}{h_w} \right)^{0.79} \cdot \left(\frac{h_w}{h_b} \right)^{1.35} \cdot h_d^{0.35} \cdot e^{-1.41}$$

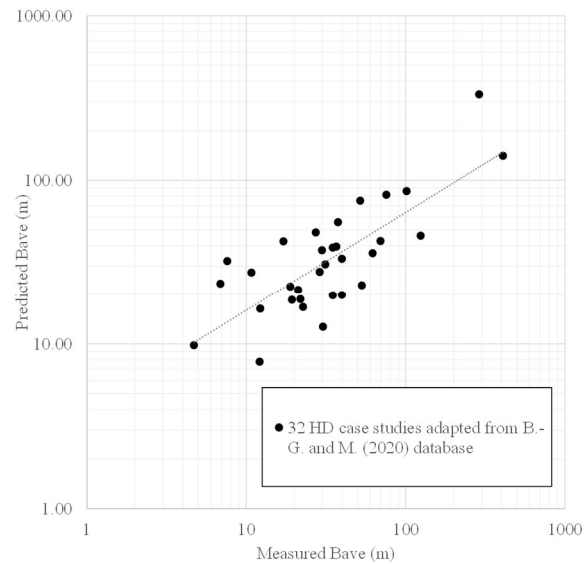


Figure 7 : Comparison of four subsamples measured and predicted Breach average width (Bave) for breached earth-rock dams adapted from Bernard-Garcia and Mahdi (2020) database.