Discussion of "Estimation of Clear-Water Local Scour at Pile Groups Using Genetic Expression Programming and Multivariate Adaptive Regression Splines" by S. M. Bateni, H. R. Vosoughifar, B. Truce, and D. S. Jeng

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Size of Database Used

The paper under discussion stated in the "Data" subsection that the authors have compiled 347 pile group (PG) scour data points from 20 sources, and the sources are cited in that section. However, the database size is inconsistent. From the 20 sources cited in the original paper, by excluding Sheppard (2003) and Moreno et al. (2016), the remaining 18 sources have 310 data points, which can be verified by checking the database compilation of Amini Baghbadorani et al. (2017) and its supplementary spreadsheet. Sheppard (2003) presents 6 PG data points, 3 of which are shared with Smith (1999), and Moreno et al. (2016) presents 1 PG data point. Consequently, the 20 sources cited in the original paper have 317 data points, which is less than 347 points mentioned in their work. These problems would have been avoided if the authors had cited the database of Amini Baghbadorani et al. (2017), which contains 365 pile group scour data.

Using Short-Duration Scour Experiments

It is well known that pier equilibrium scour depth is affected by time (e.g., Cheng et al. 2016). The same idea applies to pile groups, and long test durations are usually necessary. Care must be taken when short-duration tests are used for curve-fitting purposes, especially $t < 24$ h, where $t =$ test duration. In order to eliminate the effect of time, one method is to extrapolate the short-duration tests to equilibrium values using the various time-extrapolation formulas. Formulas for single-pier scour time evolution can be applied, a compilation of which can be found in Sheppard et al. (2011). Also, Amini Baghbadorani et al. (2017) developed time-variation formulas based on long-duration pile group scour data of Lança et al. (2013). Consequently, it is better to extrapolate the short-duration experiments to their equilibrium values as pointed out by Amini Baghbadorani et al. (2017). However, the authors used the short-duration data in their raw form for applying multivariate adaptive regression splines (MARS) and genetic expression programming (GEP).

Developing Formulas Based on Long-Duration Data

Many authors have pointed out that extrapolating short-duration scour data is not viable. For example, Franzetti and Radice (2015) truncated long-duration time-development tests and showed that extrapolation leads to erroneous results if only early-stage scour data are used, because the time development rates are different in near-equilibrium stages. As a result, the authors had two options: (1) use extrapolated scour data compiled by Amini Baghbadorani et al. (2017); or (2) discard short-duration data. We presented the results based on extrapolation of raw data in Amini Baghbadorani et al. (2017, 2018). Since we have already used the extrapolation approach, here we use the elimination of short-term data to develop scour prediction formulas.

The word "long" in long-duration scour tests is an ambiguous term. There are no universally accepted guidelines to determine what test duration is long enough. As a result, we tried different lower bounds on t and developed formulas for each case. Denoting the number of data by N, by using different lower bounds, the database size becomes: $t \geq 1$ day, $N = 97$; $t \geq 3$ day, $N = 67$; and $t \geq 7$ day, $N = 33$.

For data with $t \geq 7$ day, data sources were: Ferraro et al. (2013), Lança et al. (2013), Moreno et al. (2014), Moreno et al. (2016), and Moreno et al. (2017). For $t \geq 3$ day, additional data sources were: Sheppard (2003), Beheshti et al. (2013), Chreties et al. (2013), and Keshavarzi et al. (2018). For $t \geq 1$ day, additional data sources were: Zhao and Sheppard (1999), Heidarpour et al. (2010), Ataie-Ashtiani and Aslani-Kordkandi (2012), Imamzadehei et al. (2013), Movahedi et al. (2013), Amini and Solaimani (2018), and Yang et al. (2018).

In order to estimate scour depth, we use the following dimensionless variables as input: n, m, S'_m/D, and S'_n/D, and the output variable is $D_e/(K_s W)$. Here, S'_m and S'_n are modified spacing variables defined by: $S'_m = S_m$ if $m > 1$, otherwise $S'_m = D$; $S'_n = S_n$ if $n > 1$, otherwise $S'_n = D$; $W = nD$ or the projected width of pile group; and $K_s =$ shape factor $= 1.0$ for a group of cylinders and 1.1 for a group of squares based on the HEC-18 (Hydraulic Engineering Circular No. 18) manual as described by Arneson et al. (2012). In addition, D_e is the equivalent width of the pile group. The resulting D_e is substituted into the single-pier scour equation of the Florida Department of Transportation (FDOT)

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manual, as described by Sheppard and Renna (2010) to obtain d_{se}. Variables m, n, D, and d_{se} are defined in the original paper. The following formulas are trained based on 80% of data in each case, with the rest reserved for testing the performance:

$$\frac{D_e}{K_s W} = 1.01 m^{0.27} n^{-0.08} \left(\frac{S'_m}{D}\right)^{-0.03} \left(\frac{S'_n}{D}\right)^{-0.57}$$
$$\text{for } t \geq 7 \text{ day}, N = 33(N_{\text{train}} = 26, N_{\text{test}} = 7) \quad (1)$$

$$\frac{D_e}{K_s W} = 0.84 m^{0.39} n^{-0.07} \left(\frac{S'_m}{D}\right)^{-0.06} \left(\frac{S'_n}{D}\right)^{-0.53}$$
$$\text{for } t \geq 3 \text{ day}, N = 67(N_{\text{train}} = 53, N_{\text{test}} = 14) \quad (2)$$

$$\frac{D_e}{K_s W} = 0.87 m^{0.31} n^{-0.2} \left(\frac{S'_m}{D}\right)^{-0.05} \left(\frac{S'_n}{D}\right)^{-0.57}$$
$$\text{for } t \geq 1 \text{ day}, N = 97(N_{\text{train}} = 78, N_{\text{test}} = 19) \quad (3)$$

In addition, a MARS formula was fitted, implemented in the R software with the package earth, version 4.6.3. The original paper has already explained the basics of the MARS algorithm, therefore we do not repeat the details here. The main parameters to tune in MARS are order (the maximum number of variables multiplied by each other in each term), number of terms in the final model, and any pre-transformations on the data. Here we found that Order 1, retaining 5 terms and using tanh transformation, gives good results. The final formula was

$$\begin{aligned} D_e/[K_s W] = {} & 0.2841085 + 99.85082 \times \max[0, \tanh(m) - 0.9950548] \\ & + 44.19325 \times \max[0, \tanh(n) - 0.9950548] \\ & - 19.91011 \times \max[0, \tanh(S'_m/b_p) - 0.9950548] \\ & + 3.373851 \times \max[0, 0.9866143 - \tanh(S'_n/b_p)] \\ & t \geq 3 \text{ day}, N = 67(N_{\text{train}} = 53, N_{\text{test}} = 14) \end{aligned} \quad (4)$$

The results and comparisons are presented in Fig. 1. For $t \geq 7$ day and $t \geq 3$ day, the FDOT equation gives relatively good results, but some of the data are overestimated in $t \geq 1$ day. For the HEC-18 equation, there is an underestimation of data in all cases of $t \geq 7$, 3, and 1 day. The proposed regression formula in Eq. (1) has reasonably good performance in $t \geq 7$ day. The proposed MARS formula in Eq. (4) also shows reasonably good performance in $t \geq 3$ day. However, the regression formula in Eq. (3) struggles to predict the data with good accuracy for $t \geq 1$ day. Errors are also compared in terms of root-mean-square error (RMSE). The FDOT equation has lower RMSE than the HEC-18 equation. Also, the proposed equations have lower RMSE than existing equations for both training and test data.

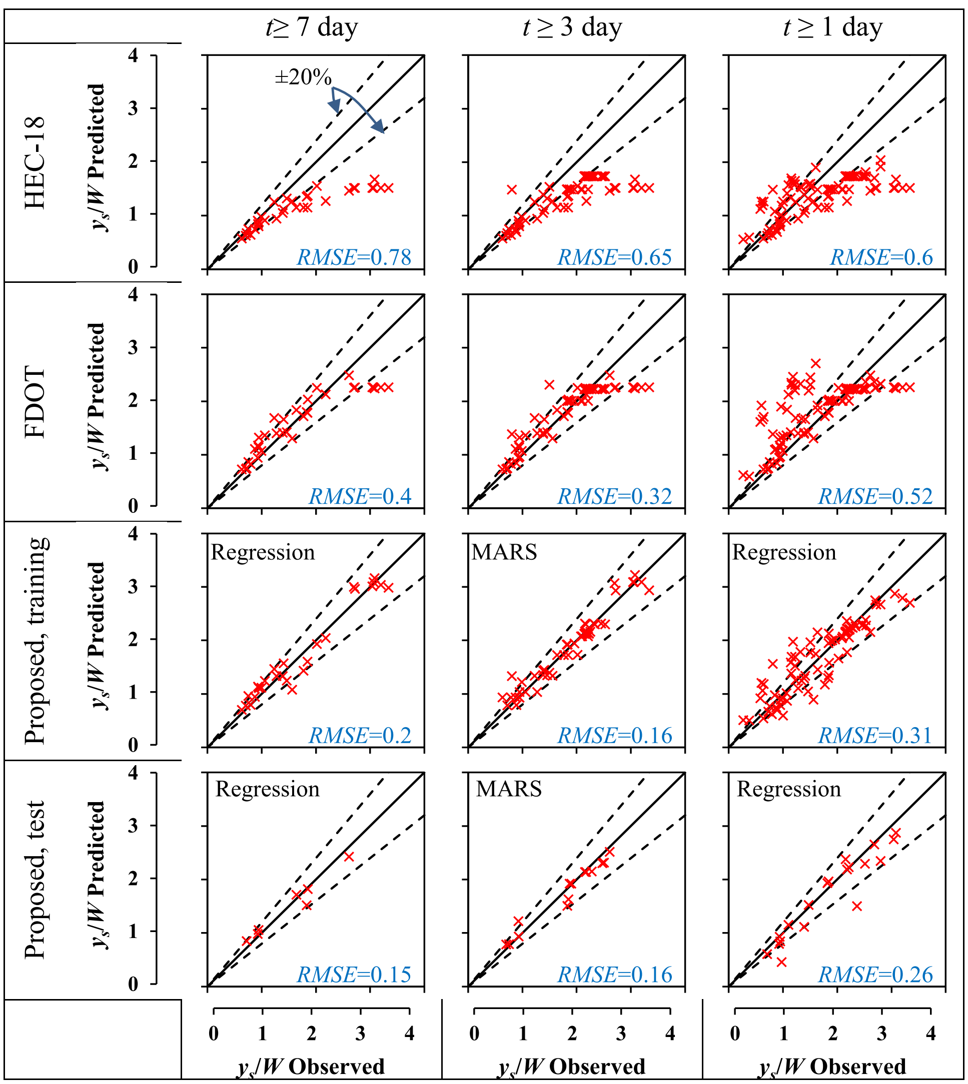

Fig. 1. Comparison of observed vs. predicted pile group scour for HEC-18, FDOT, and proposed methods.

Supplemental Data

The *R* file for developing the MARS formula is available online in the ASCE Library (www.ascelibrary.org).

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