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Discussion: Bridge pier scour prediction by gene expression programming

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Khan *et al.*'s (2012) proposed predictive Equation 12 for maximum local depths of scour at cylindrical or flow-aligned rectangular bridge piers is a purely mathematical formulation, with no demonstrated physical relationship to a phenomenon that is controlled by fluid mechanics and sediment mobility. The authors' primary variable d_s/Y is not the most convenient one: most previously published relationships make d_s/b the primary variable, since it expresses the generally strong dependence of scour depth on pier width. Other dimensionless variables are essentially of secondary importance except in the case of very wide structures in shallow depths, a situation that is not often encountered with bridge piers. Depending mainly on the secondary variable Y/b, values of d_s/b normally range from about 1·0 to an upper limit of about 2·5, with values in the range of 1·5 to 2·0 for many practical cases.

If Equation 12 is applied to realistic combinations of flow depth, pier width, Froude number and grain size, the resulting values of d_s/b are found to vary over a wide range that is not supported by experimental evidence or field experience. Three examples are provided below, where the output is expressed as d_s/b rather than d_s/Y.

Example 1. River with coarse sand bed: pier width 1 m, flow depth 3 m, velocity 1·5 m/s, grain size = 0·001 m: d_s/b calculated by Equation 12 = 0·68. The corresponding values by Laursen (1962) and Melville (1997) are approximately 2·1. (Transportation Association of Canada (2001) summarises the Laursen and Melville relationships.)

Example 2. River with medium gravel bed: pier width 0·7 m, flow depth 5 m, velocity 2·5 m/s, grain size = 0·015 m: d_s/b calculated by Equation 12 = 1·45. The corresponding Laursen and Melville values are approximately 2·5.

Example 3. River with cobble bed: pier width 0·5 m, flow depth 4 m, velocity 4 m/s, grain size = 0·1 m: d_s/b calculated by Equation 12 = 4·0. Corresponding Laursen and Melville values are approximately 2·5.

For all three examples, Laursen and Melville give d_s/b values in the range of 2·1 to 2·5, whereas the values derived using Equation 12 range from 0·68 to 4·0. The scour depth calculated by Equation 12 is highly sensitive to the Froude number, F_r, and tends towards infinity as F_r approaches 1·0, so that the equation is meaningless for near-critical or supercritical flows. In natural rivers, F_r generally correlates fairly well with grain size and does not exert an important independent influence; in fact, many experimentally based pier scour relationships discount it completely.

The inadequacy of Equation 12 as a predictor is also demonstrated by the authors' Figure 7, in which the predicted values of their ratio d_s/Y can range from about 0·25 to 2·5 times the observed value.

It thus appears that Equation 12 is not a useful predictor of design scour depths for river bridge piers and could lead to gross under-prediction or over-prediction in practical cases. Much more reliable predictive relationships, generally based on experiments but not significantly challenged by field experience, have been available for many years. The assertion made by the authors in their conclusions, regarding the utility of their model to engineers and planners, is not supported by the examples provided above.

Authors' reply

In response to the first of the contributors' comments, namely that using d_s/Y as primary variable will not result in better models, the authors developed a GEP-based model using d_s/b as primary variable (resulting equation presented as Equation 13 below) and found that the values of the coefficient of determination, R^2, were very low (0·35 for training and 0·25 for the validation data set) when compared with the GEP-based models developed for the same data sets using d_s/Y as primary variables, for which the R^2 values were 0·76 and 0·74 for training and validation data sets, respectively. The model that was developed later performed far better than the earlier one, and therefore the authors developed the GEP-based model using d_s/Y as primary variables. Furthermore, some of the authors have also used d_s/Y as primary variables for the development of their models (e.g. Azamathulla *et al.*, 2010, etc.).

$$\frac{d_s}{b} = \frac{b/L}{\left[s + \frac{51{\cdot}93}{(Y/b)}\right] * \left[\frac{(b/L)}{(s)} + \frac{F_r}{10{\cdot}91}\right]} + \left[\frac{0{\cdot}17}{(0{\cdot}59 + (F_r - (Y/b)))} + 0{\cdot}17\right] + \frac{(b/d_{50})}{\left(\frac{b}{d_{50}} + s\right) * (6{\cdot}52 + b/d_{50})} * s * (F_r + b/d_{50} - 6{\cdot}52) \quad (13)$$

Secondly, the contributors state that the values of d_s/b that result from Equation 12 vary over a wide range and do not support the experimental evidence or field experience; this can be because of one or both of the following reasons.

1. Equation 12 was developed after proper training and validation of the GEP-based model using d_s/Y as primary variable. If this model is to be applied for values other than d_s/Y, namely for d_s/b, it will require proper training and validation of the GEP-based model using a new set of variables. As the values of d_s/b were calculated just by finding the value of d_s and then divided by pier size (b), without proper training of the model, the values therefore varied widely. The model was trained and validated for d_s/b using the same data set as was used for modeling d_s/Y and the results are as shown above, which are worse in comparison with the earlier ones.
2. The value of sigma for the bed material (σ) is not available in the data given in the three examples shown in the discussion. However, for coarse bed material, σ is an important variable affecting pier scour depth. Therefore ignoring the value of σ for the bed material will definitely affect the performance of the model (Equation 12).

REFERENCES

Azamathulla HM, Ab Ghani A, Zakaria NA and Guven A (2010) Genetic programming to predict bridge pier scour. *Journal of Hydraulic Engineering ASCE* **136(3)**: 165–169.

Khan M, Azamathulla HM, Tufail M and Ab Ghani A (2012) Bridge pier scour prediction by gene expression programming. *Proceedings of the Institution of Civil Engineers – Water Management* **165(WM9)**: 481–493, http://dx.doi.org/10.1680/wama.11.00008.

Laursen EM (1962) Scour at bridge crossings. *Transactions of the American Society of Civil Engineers* **127**: 166–180.

Melville BW (1997) Pier and abutment scour: integrated approach. *Journal of Hydraulic Engineering, ASCE* **123(2)**: 125–136.

Transportation Association of Canada (2001) *Guide to bridge hydraulics*. Re-printed 2004 by Thomas Telford, London, UK.