10-1993

Closure to "Darcy-Weisbach Roughness Coefficients for Gravel and Cobble Surface"

John E. Gilley
University of Nebraska - Lincoln, john.gilley@ars.usda.gov

Eugene R. Kottwitz
University of Nebraska - Lincoln

Gary A. Wieman
University of Nebraska - Lincoln

Gilley, John E.; Kottwitz, Eugene R.; and Wieman, Gary A., "Closure to "Darcy-Weisbach Roughness Coefficients for Gravel and Cobble Surface"" (1993). *Biological Systems Engineering: Papers and Publications*. 73.
http://digitalcommons.unl.edu/biosysengfacpub/73

JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING 119:5
(September/October 1993), pp. 912-914.
Closure to "Darcy-Weisbach Roughness Coefficients for Gravel and Cobble Surface"
(January/February, 1992, Vol., 118, No. 1)

Closure by John E. Gilley,[6] Eugene R. Kottwitz,[7] and Gary A. Wieman[8]

The writers appreciate the interest expressed by the discussers in this manuscript, and are pleased to have the opportunity to further discuss this material. The discussion states that the writers have generally examined a condition already investigated in other previous studies. Reynolds number values and roughness element size for the articles referenced by the discussers are shown in Table 5. Since flow rate and Reynolds number values were not given by Ferro and Giordano (1991), data from this study are not included in Table 5.

It can be seen from Table 5 that the roughness element sizes examined by Bathurst (1978) were much larger than those used by the writers. Each of the other studies was conducted to obtain information for use on river systems. The focus of this paper, in contrast, was upland areas. Thus, Reynolds number values employed by the other authors were substantially larger than those used in this investigation.

The discussers reference material presented by Colosimo et al. (1988) to characterize flow conditions occurring in this study. It can be seen from Table 5 that the smallest Reynolds number value used by Colosimo et al. (1988) was 25 times greater than the largest Reynolds number value employed in this investigation. Certainly for river systems, with flow depths much greater than roughness element heights, Reynolds number may have a minimal effect on friction factor. However, for upland areas with much smaller water depths, friction factors may be substantially affected by Reynolds numbers. This influence is clearly shown in Figs. 2, 3, and 4.

The discussers propose (10) for estimating Darcy-Weisbach roughness coefficients. To use (10) water depth must be known. On upland areas it may not be possible to know a priori the water depth corresponding with a given rainfall or runoff condition. An equation of the form shown in Table 3 would be much easier to use in actual practice.

Widely accepted procedures are available for estimating infiltration on upland areas. If rainfall rate and duration are known, rainfall excess can be predicted. From information on rainfall excess and the downslope distance from a watershed boundary, flow discharge per unit width, q, can be calculated. For upland flow conditions where flow width is much greater than flow depth, Reynolds number can be approximated from the equation:

$$\mathrm{R} = \frac{q}{\nu} \qquad (11)$$

where ν = kinematic viscosity. Kinematic viscosity can be obtained directly from a handbook, if water temperature is known. Thus, a direct, closed-form prediction procedure for estimating roughness coefficients is provided by the equations shown in Table 3.

The discussers state that when using (10) it is not necessary to take into account the effect of particle concentration on roughness coefficients. This is because the value of d_{90} implicitly takes into account the effect of particle

---

[6] Agric. Engr., U.S. Dept. of Agric.-Agric. Res. Service, 251 Chase Hall, Univ. of Nebraska, Lincoln, NE 68583-0934.

[7] Res. Engr., Dept. of Biological Systems Engrg., 248 Chase Hall, Univ. of Nebrasks, Lincoln, NE.

[8] Res. Technologist, Dept. of Agronomy, 130 Keim Hall, Univ. of Nebraska, Lincoln NE 68583-0915.

TABLE 5. Reynolds Number and Roughness Size Used in Selected Experimental Studies

Hydraulic parameter (1)	Bathurst (1978) (2)	Bathurst et al. (1981) (3)	Colosimo et al. (1988) (4)	Gilley et al. (1992) (5)
Reynolds number	41,000–320,000	17,000–550,000	400,000–6,000,000	500–16,000
Roughness size	280–485 mm (d_{84})	12.7–63.5 mm (d_{84})	41–120 mm (d_{84})	2.5–254 mm

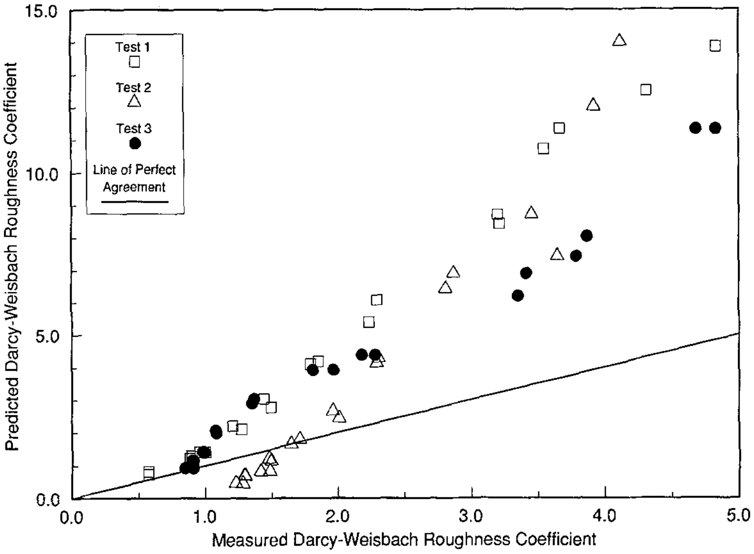

FIG. 5. Predicted versus Measured Darcy-Weisbach Roughness Coefficients for Eq. (10)

concentration. These conclusions were obtained from experimental measurements reported by Ferro and Giordano (1991).

The grain size distribution of each test series can be roughly determined from data presented in Table 1 and the equations given in Table 4. The value of d_{90} is certainly greater than 12.7 cm. Inspection of (10) shows that, for a given value of h, as d_{90} increases f also increases. Thus, assuming d_{90} = 12.7 cm should underpredict the Darcy-Weisbach roughness coefficient. Fig. 5 shows results obtained from (10) for the data collected by the writers and d_{90} = 12.7 cm. Eq. (10) generally overpredicted f even though underprediction was expected. Several predicted values were more than three times the corresponding measured values. The results clearly show that (10) is not acceptable for the conditions studied.

Ferro and Giordano (1991) conducted their experiments using a roughness element size ranging from 19 to 25.4 mm. The writers used surface cover values varying from 7 to 90% for roughness element sizes ranging from 12.7 to 25.4 mm. If the roughness elements employed by Ferro and Giordano (1991) are assumed to be circular with a diameter of 22.2 mm, an estimate can be made of the percentage cover for each of the particle concentrations. The number of roughness elements, n, arranged in a 0.3 × 0.3 m^2 reference area is shown in Table 1 of Ferro and Giordano (1991). For bed grain distributions II, III, IV, V, and VI, surface cover estimates of 2.1%, 4.3%, 8.6%, 13%, and 26% were obtained. Thus, (10) was derived for essentially one roughness element size, over a very limited particle concentration range. Information on experimental discharge rates is not available. Certainly further tests using other roughness element sizes, a much broader range of particle concentrations and a wide flow range are required before the use of (10) can be justified.