# AIR-WATER FLOW FEATURES IN SKIMMING FLOW OVER STEEPLY SLOPING STEPPED SPILLWAYS

FLORIANA M. RENNA [1], UMBERTO FRATINO [2] and JORGE MATOS [3]

[1]Ph.D. student, Dept. of Water Engineering & Chemistry,
Technical University of Bari, 4, Via E. Orabona, 70125, Bari, Italy
(Tel: +39-0805963321, Fax: +39-0805963414, e-mail: f.m.renna@poliba.it)
[2]Associate Professor, Dept. of Water Engineering & Chemistry,
Technical University of Bari, 4, Via E. Orabona, 70125, Bari, Italy
(Tel: +39-0805963321, Fax: +39-0805963414, e-mail: u.fratino@poliba.it)
[3] Assistant Professor, Dept. of Civil Engineering and Architecture, IST, Technical University of Lisbon, Av. Rovisco Pais, nº1, 1049-001 Lisbon, Portugal
(Tel: +351-21-8418145, Fax: +351-21-84197650, e-mail: jm@civil.ist.utl.pt)

Skimming flow over a stepped spillway is characterized by strong self-aeration downstream of the point of inception of air entrainment. Such phenomenon may bring some positive effects such as the mitigation of the risk of cavitation damage, as well as the increase of the oxygen exchange rate between water and atmosphere. However, the flow resistance and energy dissipation are reduced with increasing air entrainment, whereas flow bulking increases. This is particularly important on RCC dam spillways.

An experimental study has been carried out in a large-scale stepped chute assembled at the National Laboratory of Civil, Lisbon, in order to collect new air concentration data in steeply sloping skimming flows. The stepped chute is 1 m wide, 3.74 m long, and its slope is 1V:0.75H (Figure 1). For the work reported in the present paper, two geometric configurations were analysed, respectively with 0.04 and 0.02 m high steps in the constant slope. The air concentration and velocity were measured with a conductivity probe and a backflushing Pitot tube, developed and calibrated by the U.S. Bureau of Reclamation (Matos and Frizell, 2000).

In the present paper it is shown that the air concentration distribution in both rapidly and gradually varied skimming flow regions can be modeled fairly well with the analytical models developed for self-aerated flow, namely by Wood (1991) and by Chanson (1997). Further it is shown that Wood's (1991) model for predicting the development of the mean air concentration in self-aerated flow on smooth spillways was found to be applicable in skimming flow over stepped chutes downstream of the point of inception, namely for small relative step roughness (Figure 2). The results obtained in the present study are also in agreement with the findings of Matos (1999), as well as by Chanson (2002), in the gradually air-water varied flow region down the LNEC stepped chute.

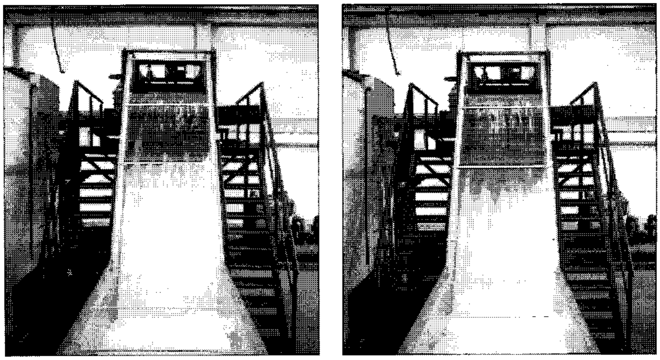

Fig. 1 Stepped chute assembled at LNEC: (a) $Q_w$ = 140 l/s, h = 0.02 m; (b) $Q_w$ = 200 l/s, h = 0.02 m.

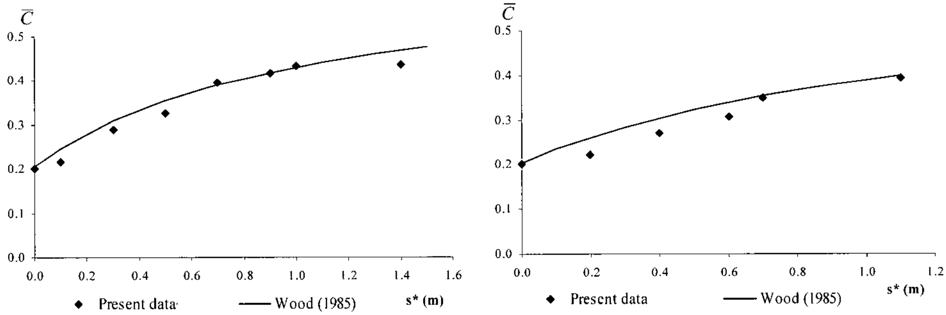


Fig. 2 Mean air concentration down the chute. Comparison of Wood's (1991) model, for $u_r$ = 0.4 m/s, against experimental data at the LNEC chute: (a) Q = 140 l/s, h = 0.02 m; (b) Q = 200 l/s, h = 0.02 m.

## REFERENCES


Chanson, H., 1997. Air bubble entrainment in free-surface turbulent shear flows. Academic Press, London, UK.

Chanson H., 2002. The hydraulics of stepped chutes and spillways. Balkema ed., ISBN 90 5809 352 2.

Matos, J., Frizell, K. H. 2000. Air concentration and velocity measurements on self-aerated flow down stepped chutes, Proc. 2000 Joint Conf. on Water Resources Engineering and Water Resources Planning & Management, ASCE, Minneapolis, USA (CD-ROM).

Matos J., 1999. Emulsionamento de ar e dissipação de energia do escoamento em descarregadores em degraus. Research Report, Technical University of Lisbon, IST, Lisbon (in portuguese).

Wood I.R., 1985. Air water flows. Proc. XXI IAHR Congress, Melbourne, Australia, Keynote address, pp. 18-29.

Wood I.R., 1991. Free-surface air entrainment on spillways. In Air Entrainment in Free Surface Flows, IAHR Hydraulic Structures Design Manual No. 4, Hydraulic Design Considerations, I. R. Wood ed., Balkema Publ., Rotterdam, The Netherlands, 55-84.