FLOW DISTRIBUTION IN STREET INTERSECTIONS DURING STORM EVENTS, UNDER SUBCRITICAL CONDITIONS

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ABSTRACT

During storm events in large cities, floods commonly occur in such way that water circulates through streets as in a channel network causing material and human losses. To be able to intervene efficiently it is necessary to know the dynamics of the overland flow. When circulates through streets, the flow may be considered unidimensional and therefore it is easy to study. In the intersections though, where water masses coming from different directions merge, mix and redistribute towards exiting streets, the flow will be, at least, bidimensional. To determine the working scheme of the network, it is crucial to know how the different flows redistribute in the intersections and, as it is extremely difficult to design a bidimensional scheme which solves the whole network, it is proposed to experimentally determine a flow-distribution model at the intersections.

Nanía Escobar (1999) studied the flow distribution in the street intersections under supercritical conditions. In this work it is studied the flow behavior in the intersections in subcritical conditions with the goal of obtaining a flow distribution model. To do it, we perform several assays in an experimental device which simulates the intersection of two perpendicular streets, with square corners, and horizontal. With the objective of cover the largest possible range, assays were performed in different boundary conditions, both at the entrance and at the exit of the intersection. Conditions at the entrance were the input flow rates (x and y directions), while downstream conditions were modified through the use of end weirs with different heights at the end of both exiting streets. We measured water depths in the entering streets (in the section immediately before the intersection) and in three sections of the exiting streets, as well as the flow rates in the four streets.

Several phenomena were observed during the experimental work, being the most noticeable the formation of a flow separation and recirculation zone at the exiting streets. This zone may be as wide as to two thirds of the street width and persists until the end of the street. Nevertheless, due to the lack of appropriate equipment, the phenomenon could not be studied in detail, and it will have to be studied in the future.

It is concluded from the results analysis that the flow distribution depends on both, upstream and downstream conditions, which is not unexpected given the subcriticality of the flow. Nevertheless, it is demonstrated that downstream conditions influence is higher and increases with the water level in the system.

Several variables may be used to define downstream conditions, i.e. water-depths, Froude Numbers or Froude Index (ϕ), all of them considered in the last section of the exiting canal. Among them, Froude Index gives a better explanation of the phenomenon and it was observed that the flow rate will be higher in the street that has a higher Froude Number. To quantify this tendency it is defined a cubic function which correlates ϕ and the exiting-flow fraction in the x direction. Regarding the upstream conditions, they can be equally characterized as the fraction of inflow in the x-direction, or as the fraction of entry power in the x direction. It is demonstrated that, for the studied range, where flow rates are low and energy appears as water-depth, both variables are practically equivalent. With the same downstream conditions, we demonstrate that the exiting flow will be higher in the direction that has the highest flow rate (and the highest flow power).

In order to take into account both upstream and downstream conditions when establishing what will be the flow distribution, we built a new variable that includes both, Froude Index and the entering flow ratio in the x direction (or the power fraction). It is demonstrated that there is a lineal relation between the new variable, the Global Index, and the exiting flow ratio in the x direction. In this way, having the Froude numbers at the exiting streets and the entering flow rates, it is possible to calculate the flow rates at the exit of the intersection.

Finally we have compared the distribution model obtained with two different numeric models, one bidimensional which solves the complete Saint-Venant equations, and another unidimensional based in the energy conservation equation. In the first case, results are similar to the obtained with the experimental, while in the second case important deviations are observed when the entering flow rates are notably different in both directions. We adapted this model to the experimental by the introduction of energy losses in the beginning of the exiting streets.