# Numerical modelling to estimate hydraulic efficiency of continuous transverse grates

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## Highlights

- Development and calibration of a 2D-3D model to estimate hydraulic efficiency of continuous transverse grates for urban drainage systems
- Comparison between numerical simulations and experimental tests to validate hydraulic efficiency of continuous transverse grates

## Introduction

Most of the climate projections for the Mediterranean area up to the end of the Century show a significant increase in the number of extreme events, while it is expected a decrease in the total amount of rainfall along the year [1]. Heavy rainfall events usually happen between August and November, after periods without significant precipitations, where foliage and other urban sediments have a higher potential to generate clogging while settling inside the conduits and covering the inlets. This latter could represent one of the most problematic aspects for maintaining a healthy and efficient drainage system, as inlets and manholes are direct responsible for connecting surface and underground system. In this sense, Gómez M. and Russo B. been years investigating how to quantify and improve the inlet efficiency estimations, while exploring new methodologies and theories with the help of a 1:1 scale platform located in the hydraulic laboratory of the Universitat Politècnica de Catalunya (UPC), Barcelona. The hydraulic behaviors of drainage elements are being studied by several other authors [2] and Gomez and Russo stand out because of their innovative proposal for the efficiency estimation of single grated inlets [3] and continuous transverse grates on paved areas [4] [5]. In both cases, it was proved that the inlet hydraulic efficiency can be directly related to its design and to the approaching flow behaviors generated by lane geometries. The hydraulic efficiency of any inlet could be easily summarized as the ratio between intercepted and approaching flow, expressed per meter of grate, as it is shown by the Equation (1):

$$E = \frac{q_{int}}{q} \quad (1)$$

where *E* is the hydraulic efficiency of continuous transverse grates per meter of grates, $q_{int}$ is the intercepted flow rate per unit width intercepted by the grate (L/s/m) and *q* is the flow rate per unit width flowing on the street (L/s/m). A considerable number of tests were completed employing the above-mentioned UPC platform and a total of 7 common grates were studied to develop and validate the just presented efficiency equation. The equation was improved to refine geometries dependencies and to ease the adoption at a large scale for untested squared grates too [5] [6]:

$$E = \alpha \times F \times \left(\frac{y}{L}\right)^{0.812} + \beta \quad (2)$$

where $\alpha$ and $\beta$ are parameters that depend on the geometry of the grate, *L* is the effective length in the main direction of the flow, *F* is the Froude number and *y* is the flow depth (both generated immediately upstream of the grate). To speed up implementations and validations for any type of inlet geometries, it was chosen to attempt numerical solutions with the expectancy to swap laboratory tests with computer equivalent simulations. In this sense and following previous experiences [7][8], a hybrid 2D/3D model of the UPC platform was built with the commercial CFD software Flow3D [9].

# Methodology

The numerical model pretends to replicate the UPC platform with details in all its elements: upper tank, water source, platform and grate (Figure 1). Specific effort was given to the inlet modelling by using Google SketchUp to obtain a solid Stereolithography (STL) copy, which was the required format to work with Flow3D. The image shows the model setup for continuous transverse grates, which are the object of this abstract; for lateral inlets simulations, the grate was located at the very left border of the platform.

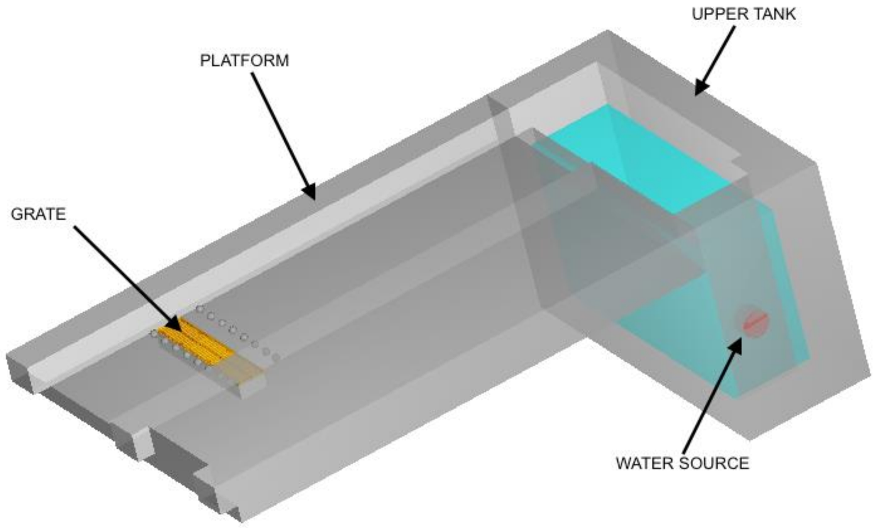


**Figure 1.** Set-up in Flow 3D of continuous transverse grates.

Different meshing criteria were applied to the various part of the model, gaining efficiency and decreasing computational cost. The biggest improvement was reached by nesting the fully 3D model (based on Navier Stokes Equations) with the approximated 2D Shallow Water Equations in some specific areas such as over the platform. Considering available hardware capabilities (Case computer Intel Core 2 Duo, 2.3 GHz and 12 GB RAM), the maximum cell size was set at 4cm for the tank, 2cm for the platform area, while decreasing down to 1 cm around the inlet zone, resulting into a total number of 1.162.355 cells. The model was forced to adopt the Re-Normalization Group (RNG) to emulate turbulence variability as the most suited for these studies, following Flow3D User manual indications [10]. Initial Conditions (IC) were set as needed, ensuring constant inflow rate (50 l/s and 100 l/s) through the water source, as well as Boundary Conditions (BC) to emulate reasonable flow behaviors at computational mesh limits (wall, outflow, symmetry).
Simulations were performed for a wide range of combinations of transversal and longitudinal slopes, trying to reproduce the most common road existing geometries. Hence, varying the model slope from 0 to 10% towards the direction of the flow and from 0 to 4% perpendicularly, it was possible to emulate exactly how the real UPC platform behaves and thus comparing numerical with experimental results.

# Results and discussion

Simulations were conducted after model calibration, which was achieved by comparing a pair of lab tests with model simulations and leaving the others for model validation.
Postprocessing was used to transform results from 1,5 meters length (wide of the platform), to unit value (1-meter length), simplifying implementation and eventual comparison in further studies.
Hydraulic efficiency of continuous transverse grates is usually higher than single lateral inlets; the effect they produce over the flow pattern is far greater and thus more effective if compared with conventional catching elements. Despite this, its applications are strictly limited to large paved areas such as squares, parking and airstrips.
The results can be considered as satisfactory, showing high level of correlation between experimental and numerical data (Figure 2) and confirmed also by the value of the R coefficient which is equal to 0.98.
The comparison and the validation between the two methods, opened a brand-new era for laboratory tests, offering a path to shift from traditional 1:1 scale lab equipment to the about-limitless possibility provided by modern CFD software. Results analysis also revealed a high level of accuracy with respect to water depth and velocities distribution all along the whole platform, as it is possible to appreciate in below images (Figure3).

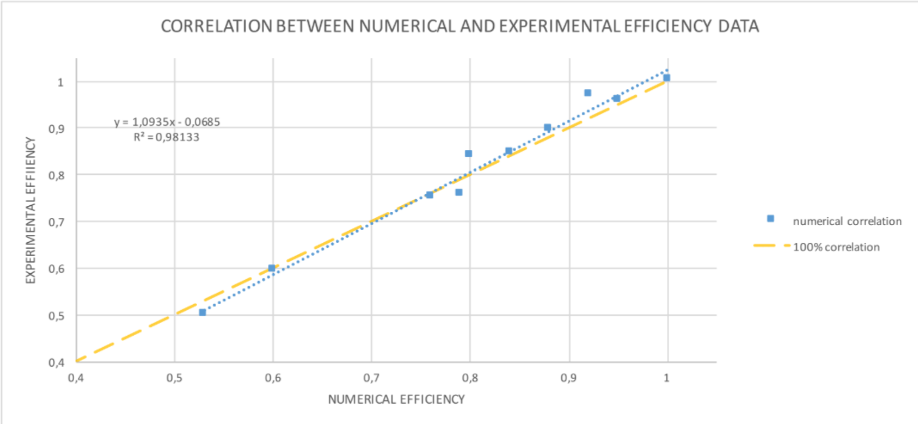


**Figure 2.** Comparison of hydraulic efficiency between experimental and numerical simulation of continuous transverse grates.

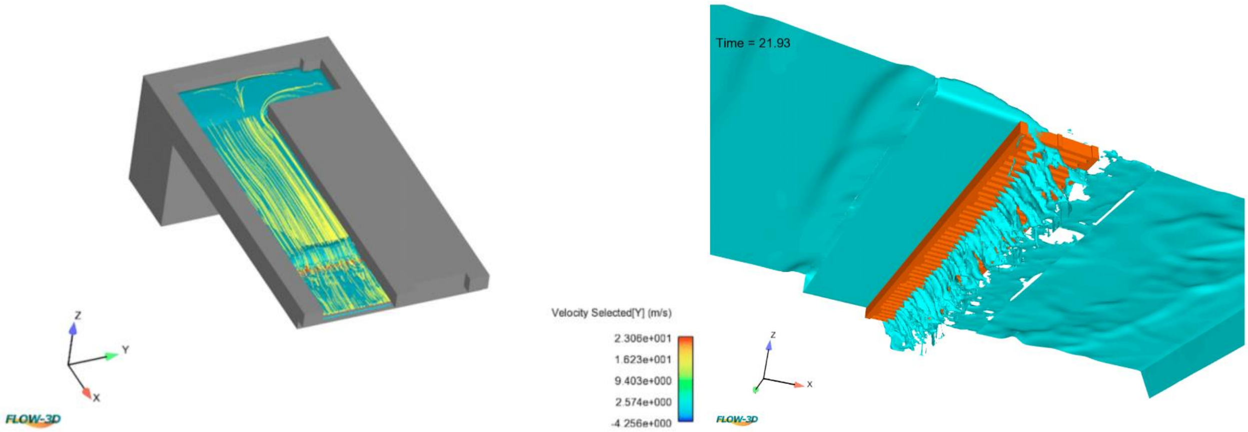


**Figure 3. LEFT:** Visualization of velocities field. Transversal lopes 0%, longitudinal slopes 4% and flowrate equal 100 l/s
**RIGHT**: grate detail during simulation (personal elaboration).

# Conclusions and future work

The achieved results demonstrated the huge potential to adopt numerical modelling whereas lab simulations to estimate grate efficiency were not available or too complex to achieve due to lack of resources or knowledge. Although the computational time required to perform the simulations was quite high (due to hardware limitations), the accuracy of the results is extremely satisfying, justifying the adoption of the 3D modelling. Offering CFD solutions has an alternative to common lab procedures, opened new horizons for the adoption of these models in the field of urban hydrology, whilst any good modelling needs to be validated before being implemented, this paper could provide valid references to anybody approaching the topic.

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