

Hydraulic efficiency of macro-inlets

Efficacité hydraulique des grands avaloirs à grilles

Manuel Gómez Valentín, Beniamino Russo

FLUMEN Research Group
Technical University of Catalonia,
Jordi Girona 1-3, 08034, Barcelona, Spain
manuel.gomez@upc.edu ; beniamino.russo@upc.edu

RESUME

Quand les bassins urbains montrent une faible capacité pour introduire l'écoulement dans le système d'égouts, des paramètres hydrauliques (la profondeur de flux et la vitesse) peuvent grandir et atteindre des niveaux dangereux pour le piéton et la circulation automobile. Quand ces flux arrivent au centre ville il faut introduire toutes les eaux pluviales et leurs grands volumes avec des structures spéciales. Une solution pour ce problème consiste à l'utilisation des macro-grilles avec une haute efficacité hydraulique. Dans cette communication, les données expérimentales concernant quelques essais de macro-grilles sont présentés. Une analyse de ces données est utile pour concevoir des nouveaux systèmes d'admission pour grands débits, efficaces et sûrs.

ABSTRACT

When urban catchments present inlet systems with a poor capacity of conveying runoff into the sewer system, hydraulic parameters (flow depth and velocity) can grow up to reach dangerous levels for pedestrian and vehicular circulation. When these flows reach depressed areas, stormwater stores in these areas big volumes of flow that need particular hydraulic structures to discharge into the sewer systems as soon as possible. A feasible solution for this problem consists on the use of macro-grates with a high hydraulic efficiency. In this paper experimental data concerning some macro-grates tests are presented. An accurate analysis of these data is useful to design efficient and safe inlet systems.

KEYWORDS

Drainage, hydraulic efficiency, macro-grates, Urban flooding.

1 INTRODUCTION

When an urban catchment presents an inlet system with a poor collecting capacity to introduce runoff into the sewer system due to a lack of inlets, stormwater hydraulic parameters (flow depth and flow velocity) can grow up to reach dangerous levels for the pedestrian and vehicular circulation. When these flows reach depressed points, stormwater stores in these areas big volumes that need particular hydraulic structures to get waters into the sewer systems as soon as possible. A feasible solution for this type of problem consists on the use of macro-grates of urban drainage with a high hydraulic efficiency. Frequently the location of these structures in the outlet of a sub-catchment with a problem of lack of inlets upstream or in depressed areas may result the one solution for technicians and engineers to fight against problems concerning floods. In this paper experimental data concerning 3 tested macro-grates and a comparative analysis are presented. An accurate analysis of these data can result useful for the engineers to design an efficient and safe inlet system and useful for the foundries to establish design rules to improve the hydraulic efficiency of their products.

This study extends the results of a research line carried out by FLUMEN research group in the field of hydraulic inlet efficiency (Gómez and Russo, 2005; Martínez and Gómez, 2000). Particularly the aim of the last experimental campaign was to extend the results obtained in the past to a larger range of inlets.

Other possible solution used to collect big volumes of stormwater into the sewer system is the combination of 2 or more inlet elements.

Specifically a particular surface drainage structure consisting of two macro-grates combined in an L shape was tested in the Hydraulics Department of the Technical University of Catalonia (UPC) and the results are presented in this paper too.

2 METHODS

2.1 Hydraulic efficiency of surface drainage elements

The hydraulic efficiency of a surface drainage element is defined as the ratio of the intercepted discharge (Q_{int}) by the structure to the total discharge circulating in the curb (Q):

$$E = \frac{Q_{int}}{Q} \quad (1)$$

In the 1997 the mixed company for the management of the sewer systems of Barcelona, Clavegueram de Barcelona S.A. (Clabsa), and the Hydraulics Department of the Technical University of Catalonia (Spain) promoted a new research line in the field of the road grates efficiency. The most common grates were tested in a laboratory by a platform that can simulate the hydraulic behaviour of a lane 3 m wide. On the basis of these real scale tests and the studies of the HR Wallingford (Spaliviero and May, 1998) a potential law expression was achieved and a reliable methodology concerning efficiency calculation was obtained (Martínez and Gómez, 2000).

$$E = A \left(\frac{Q}{y} \right)^{-B} \quad (2)$$

where:

Q is the total flow approaching the inlet (l/s)

y is the hydraulic depth upstream to the grate (mm)

A and B are two characteristic parameters related to the grate geometry:

Equation 2, corresponding to one lane of 3 meters wide, was generalized for each type of geometric configuration of the roadway (Russo *et al.*, 2006). For a roadway with a width greater than 6 meters, the equation (2) becomes:

$$E = A \cdot \left[\frac{Q}{y} \cdot \frac{1 - \left(1 - \frac{3 \cdot I_x}{y}\right)^2}{1 - \left(1 - \frac{x \cdot I_x}{y}\right)^2} \right]^{-B} \quad (3)$$

where I_x is the transversal slope (m/m) and the other parameters have been described before.

2.2 Hydraulic structures tested

In the first experimental campaign (Martínez and Gómez, 2000) FLUMEN Research Group tested some grates with limited dimensions. In fact, normally, Public Administration of Barcelona City requires drainage grates with small widths (around 30 cm) in order to include the inlets in the curb totally.



Figure 1. – Curb in Barcelona with tiles of 30 cm.

In case of storms, several catchments present high and dangerous hydrographs due to the poor surface drainage capacity of the upstream areas. This lack of drain capacity is often due to a lack of inlets or to a poor capacity of the existing inlets. A feasible solution for this type of problem consists on the use of macro-grates of urban drainage with a high hydraulic efficiency. Frequently the location of these structures in the outlet of the sub-catchments may result the one solution for technicians and engineers to fight against problems concerning floods (it is more and more difficult to persuade Public Administrations to operate continuous hydraulic rehabilitations on urban roads while punctual solutions may result to have less impact).

In order to evaluate the hydraulic capacity of surface drainage elements that allow a quick discharge of stormwater volumes stored in the depressed areas of the cities, some non-conventional hydraulic structures were tested in a experimental campaign.

Particularly the following types of structures were tested:

- Single macro-grates
- Macro-grates combined in an L shape

In this paper we define macro-grates as special inlets with great dimensions (approximately 50 cm x 100 cm), elevated void area and generally high hydraulic efficiency. These dimensions are usual for the American foundries, but normally drainage inlets produced in Europe present smaller sizes.

In the first case, three macro-grates actually used in the city of Barcelona were tested and a comparative study was carried out, while in the second case a particular structure made up by 2 macro-grates was considered (2 macro-grates combined in an L shape locating the short side next to the curb).

2.2.1 Testing on single macro-grates

The first phase of the experimental campaign concerns tests on single macro-grates. Typology and geometrical characteristics of the 3 macro-grates tested are shown in the Figure 2 and Table 1. The macro-grates were tested in the hydraulic laboratory of the UPC by a platform that can simulate the hydraulic behavior of a roadway corresponding to one lane of 3 meters wide (Fig. 3).

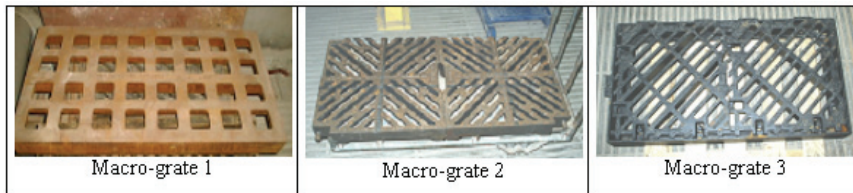


Figure 2. – Macro-grates tested.

Macro-grate	Length (cm)	Width (cm)	Total Area (m ²)	Void Area (m ²)	Number of longitudinal bars n _l	Number of transversal bars n _t	Number of diagonal bars n _d
1	97,5	47,5	0,4631	0,1400	3	7	0
2	99,9	50	0,4995	0,1760	1	3	28
3	100	50	0,5000	0,2012	1	3	21

Table 1. – Geometric parameters of the tested macro-grates.

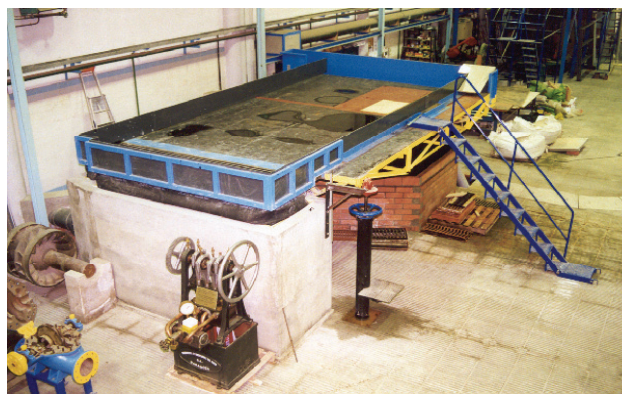


Figure 3. – UPC platform.

Macro-grates were tested according to the following protocol:

- Longitudinal slopes: 0%, 0.5%, 1%, 2%, 4%, 6%, 8%, 10%
- Transversal slopes: 0%, 1%, 2%, 3%, 4%
- Circulating flows: 25 l/s, 50 l/s, 100 l/s, 150 l/s

2.2.2 Testing on macro-grates combined in an “L” shape

Other possible solution used to collect big volumes of stormwater into the sewer system is the combination of two or more elements of surface drainage. In the second phase of the experimental campaign, a particular structure consisting of 2 macro-grates type 3 combined in an L shape (as shown in the Fig. 4) was tested.



Figure 4. – Surface drainage structure tested.

The structure was tested according to the previous protocol, but some geometric configurations of the platform were not tested due to the hydraulic limits of the measurement of the captured flows.

3 RESULTS AND DISCUSSION

The experimental results showed that the potential equation (Eq. 2) is able to represent the hydraulic behavior of the macro-grates, while gives not very good results for the two macro-grates in the L shape. In the following figures experimental data and the correlation factors are shown.

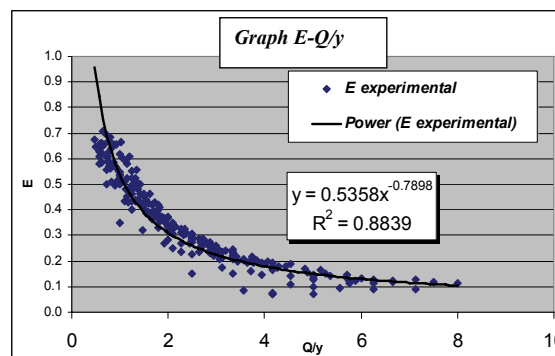


Figure 5. –Experimental data and potential trendline for the macro-grate 1

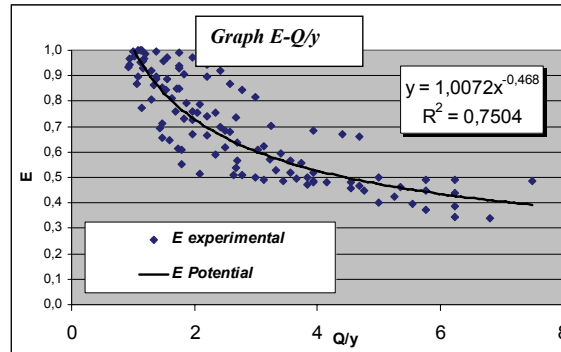


Figure 6. –Experimental data and potential trendline for the 2 combined macro-grates-

In order to determine information about the best hydraulic design, a comparative analysis of the experimental data obtained for the three macro-grates was carried out. Comparative graphs for a circulating flow of 150 l/s are shown in the Fig. 7.

Comparing data concerning the macro-grates and the other ones related to the “L structure” (for transversal slope $ix=0\%$), it is possible to observe a great difference in terms of hydraulic efficiency. This “L structure” is actually used in depressed areas of Barcelona and in the outlet of urban basins presenting a lack of inlets upstream.

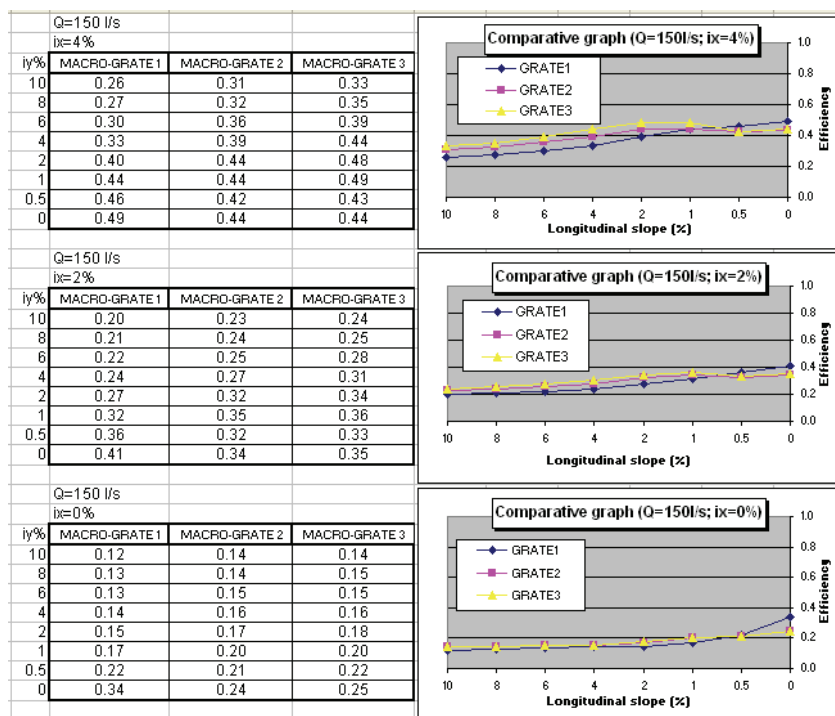


Figure 7. – Comparative data about hydraulic efficiency for a circulating flow of 150 l/s.

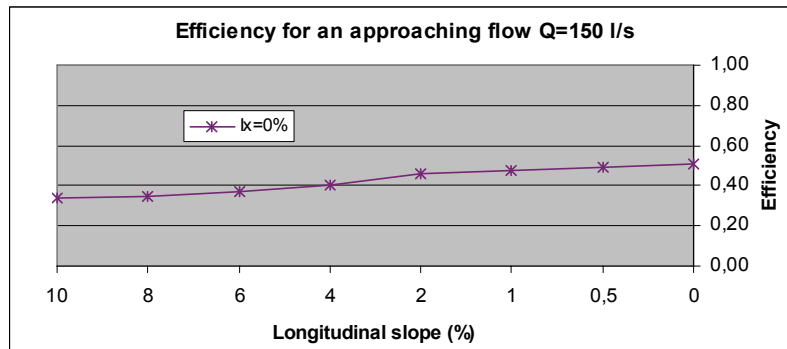


Figure 8. – Efficiency data for the combined macro-grates (transversal slope $i_x=0$).

4 CONCLUSIONS

Considering experimental data results, it is possible to make the following remarks about the comparative analysis:

- The macro-grates analyzed present a hydraulic efficiency depending on street geometry, the approaching flow and flow depth.
- Generally efficiency E grows increasing transversal slopes and reducing longitudinal slope, while considering the approaching flow, efficiency E is higher for low circulating flows.
- The macro-grates present a “residual” and almost constant efficiency for high longitudinal slopes and low transversal slope.
- The macro-grates present a behavior like to the conventional grates analyzed in the previous experimental campaign, so it is possible to use UPC efficiency methodology for these surface drainage elements too.
- Macro-grate 1 presents efficiency values higher than other macro-grates analyzed for longitudinal slopes lower than 1%. In these conditions, the great dimensions of the slots facilitate flow capture but this hydraulic design is forbidden by the norm in force EN124 (For this type of grate, the maximum width of the slot must be included in the range 32-43 mm). Increasing transversal slopes, the two-dimensional behavior of the flow reduces this effect due to the hydraulic design of the macro-grates 2 and 3 that present slot in the flow direction.
- For longitudinal slope higher than 1%, macro-grates 2 and 3 present higher efficiency values than macro-grate 1. In fact, due to its design (longitudinal and transversal stout bars) macro-grate 1 could not intercept all the flow approaching the inlet because a considerable amount of flow by-passes the inlet, not finding any slot area (Fig. 9), while the others macro-grates present some slots in the totally of the grate width.



Figure 9 – Problems associated to the hydraulic design of the macro-grate 1.

- Normally efficiency values for the macro-grate 3 are the highest, but the relative difference are not very significant (5%-10%) for the geometric conditions and the approaching flows tested.
- The structure formed by 2 macro-grates combined in an L shape, presents a hydraulic efficiency higher than the other grates one. The difference is in the 100% -150% range.
- This type of structures can be used in depressed areas of the cities and in the outlets of urban basins presenting a lack of inlets upstream. Its good hydraulic capacity represents an economic and, above all, a local solution compared to normal grates.

AKNOWLEDGEMENTS

The authors would like to express their sincere thanks to Fundación Agbar (Barcelona, Spain) for its support in this work.

LIST OF REFERENCES

- CCRCO (Clark County Regional Flood Control District), 1999. Hydrological criteria and drainage design manual. Clark County, USA.
- Federal Highway Administration (FHWA) 1984. Design of urban highway drainage. FHWA, Office of Technology Applications, Washington, D.C., USA.
- Gómez M. and Russo B. 2006. Comparative study among different methodologies to determine storm sewer inlet efficiency from test data. 10th International Conference on Urban Drainage. Copenhagen, Denmark.
- Guo J. C. Y., 2000. Design of grate inlets with a clogging factor. *Advances in Environmental Research* 4 (2000) 181-186.
- Izzard C. F., 1946. Hydraulics of runoff from developed surfaces. *Proc. Highway Research Board*, vol. 26. Washington D. C., USA.
- Martínez P. and Gómez M., 2000. Estudio de eficiencia de la captación de rejillas. XIX Congreso Latinoamericano de Hidráulica, Córdoba, Argentina. (in spanish)
- Russo B., Gómez M. and Martínez P. 2006. A simple hydrological approach to design inlet systems in urban areas according to safety criteria. 7th International Conference on Hydroscience and Engineering (ICHE-2006), Philadelphia, USA.
- Russo B., Gómez M. and Martínez P. 2006. A simple hydrological approach to design inlet systems in urban areas according to safety criteria. 7th International Conference on Hydroscience and Engineering (ICHE-2006), Philadelphia, USA.
- Russo B., Gómez M., Martínez P. and Sánchez H., 2005. Methodology to study the surface runoff in urban streets and the design inlets systems. Application in a real case study. 10th International Conference on Urban Drainage. Copenhagen, Denmark.
- Spaliviero F. and May R. W. P., 1998. Spacing of road gullies. Hydraulic performance of BS EN 124 gully gratings. HR Wallingford, United Kingdom.
- Wong S. W. and Moh Wung-Hee T., 1997. Effect of maximum flood width on road drainage inlet spacing. School of Civil and structural Engineering, Nanyang Technological University, Nanyang Avenue. *Water Science Tech.* Vol. 36, No. 8-9, pp.241-246.
- Urban Drainage and Flood Control District (UDFCD), 2001. Urban storm water drainage design criteria manual (USWDCM), Vols 1 and 2, Denver, USA.