Technical Note

A Simple Aid for Designing Sewers

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Abstract

A method for constructing design charts for the rapid selection of sewer diameter and gradient is described. A variety of design criteria for sewer capacity and minimum gradient can be incorporated in the chart, which may be adapted for different ranges of pipe diameter and material. The use of the chart should ensure that the most economical combination of pipe diameter and gradient can be chosen without the need for calculation.

Key words: **Sewer design; sewer reticulation.**

Introduction

There is a considerable variation in the design criteria and other rules which are applied to the design of sewers. The general principles are that a sewer should have sufficient capacity to convey the maximum predicted flow and have a sufficiently steep gradient to achieve a velocity or boundary shear stress which is high enough to prevent accumulation of solids in the sewer.

To design a sewer which satisfies the relevant design rules, and is also as economic to construct as possible, can be quite a lengthy procedure. For instance, using the Wallingford tables[1] or charts[2], it is straightforward to select a pipe diameter and gradient to pass the maximum peak flow. However, to check whether this combination satisfies the requirements for minimum velocity (or shear stress) at the daily peak flow involves a number of additional steps; therefore it is impractical to check every combination of flow, pipe diameter and slope. Accordingly, simple rules of thumb are often applied which can lead to uneconomic design and low levels of sewer utilization, resulting in the sewer having excessive spare capacity.

A quicker method of checking minimum velocity is to use Macedo's modification of the Manning equation[3,4], which gives a reasonably accurate approximation of velocity from the flow and gradient only, without having to determine the depth of flow. Surprisingly, velocity is independent of pipe diameter. Even using this approach there are still two stages in selection, (a) determining capacity and (b) checking the minimum velocity requirement, or *vice versa*. If the flow at the daily peak is more than half the maximum flow, satisfying the velocity requirement for the daily flow will automatically ensure that the maximum capacity requirement is also met. However, for some design criteria, such as those which apply in Zimbabwe, this is not the case; therefore both have to be checked, which is where a simpler method would be welcome.

Design approach

The alternative method is to construct a design chart incorporating the applicable design criteria for peak discharge and minimum velocity (or shear stress) so that the most economical combination of pipe diameter and slope can be selected in a single operation without the need for calculation.

The design chart in Fig. 1 is based on the rules which are applicable to the design of sewer reticulation to serve low-income settlements in Zimbabwe, but the principles can be applied to any other set of criteria. In Zimbabwe, sewers are required to accommodate a flow of 5.25 times the average dry-weather flow (ADWF) and achieve a self-cleansing velocity (here assumed to be 0.6 m/s at the daily 2-hour peak of 2 × ADWF). Flows for proportional depths less than 0.2 have been omitted, as this is the minimum commonly assumed in the design of sewers.

The chart was constructed using the Colebrook-White equation, a roughness height of 3.0 mm, and the diameters of the asbestos-cement sewer pipes commonly used in sewer reticulation in Zimbabwe. It if is considered that the extra accuracy derived from using the Colebrook-White equation does not justify the additional effort required to produce the chart, Manning's or any other equation can be used instead. A spreadsheet was developed giving the maximum capacity of the sewer and the discharge at a velocity of 0.6 m/s for a range of pipe sizes and gradients. The discharge for the 0.6 m/s velocity was determined by trial and error simply by adjusting the depth of flow until the desired velocity was obtained. It is not necessary to calculate flows for gradients which produce a minimum flow higher than the maximum flow. The discharges are then divided by the relevant peak factors so that, when plotted, the two curves for each pipe diameter are expressed in terms of ADWF. The flow could also be divided by the average sewage contribution per connection so that the chart is then expressed in numbers of connections. Depending on the design criteria employed, the two curves for any particular pipe size may, or may not, intersect at a feasible gradient. If the minimum gradient criterion is based on the concept of boundary shear stress, also known as tractive force, this can be calculated instead of velocity and set to its minimum permissible value – again by adjusting the proportional depth.

To use the graph to determine the minimum pipe diameter and gradient for a given flow, enter the ADWF and read across horizontally until one or more of the

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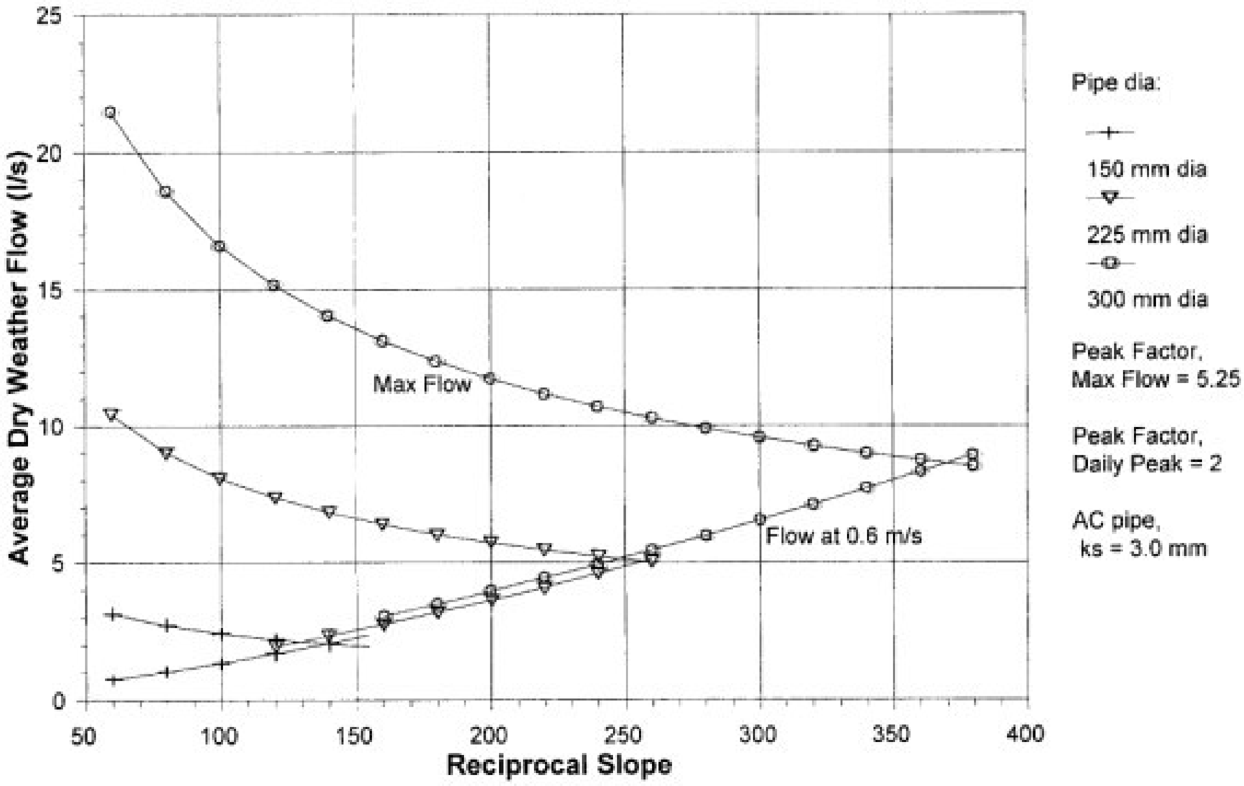

Fig. 1. Sewer design chart

curves is intersected, the corresponding reciprocal gradient read from the x axis is then the flattest that the particular pipe size can be laid for that flow. If the line intersected is the lower of the pair, the minimum velocity (or other minimum slope) criterion is controlling, and if it is the upper line it is the sewer capacity which is limiting. To check whether a given combination of diameter and gradient is adequate, all that is necessary is to check that the point corresponding to the appropriate gradient and flow lies between the upper and lower curve for the relevant pipe diameter. It can also be immediately seen whether a smaller pipe could be used.

For example, to accommodate an ADWF of 10 l/s, there is a choice of a 225 mm dia. pipe laid at 1:60 or a 300 mm dia. pipe at 1:280. The 10 l/s line would intersect the lower line for the 300 mm pipe at a gradient of about 1:400, but a sewer at this slope would not meet the requirement for capacity at maximum flow. For an ADWF of 5 l/s there would be a choice of either a 225 mm dia. or 300 mm dia. pipe laid at 1:250.

Implications of use

One commonly applied rule for sewer gradients was Maguire's rule, i.e. the gradient should be steeper than one over ten times the pipe diameter (in inches). Marriot[5] proposes the use of a similar but less conservative rule, i.e. restricting gradients to a minimum of the reciprocal of the diameter (in mm). Examination of the design chart, which is based on conservative criteria, shows that this rule is also unnecessarily restrictive, particularly for larger pipe diameters. Should a lower factor be applied for the maximum capacity, or less restrictive criteria be applied to the daily peak flow, the difference between Marriot's 'Metric Maguire' rule and the rigorous application of the design criteria will be even greater.

Surveys of sewers in the UK[6] showed that the two factors contributing most to causing blockages were workmanship and the level of utilization of the sewer. Therefore any method or rule which tends towards the selection of a larger pipe size is likely to add to, rather than reduce, the frequency of blockage. Use of the design chart should ensure that the best combination of gradient and diameter can be selected quickly, therefore the provision of over-capacity, which may cause future maintenance problems, will be avoided.

References

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