Fact Sheet

SP4: Development of operational strategies and user guidelines for ventilation

1. Introduction

The objective of the present investigation into ventilation rates in sewerage systems was to develop methods for determining:

- Ventilation rates in gravity sewers with no forced ventilation system and
- Ventilation rates through drop structures.

2. Measurement of ventilation rates in gravity sewers with no forced convection

Ventilation rates in a number of gravity sewers were determined using carbon monoxide as a tracer. The tracer was injected at the upstream location as a pulse. There was minimal axial dispersion of the pulse as it moved downstream and the travel time could therefore be determined reliably.

Tests results were obtained from 3 gravity sewers operating without a forced convection ventilation system. Air velocities in the first of the test sewers were about 50% of the water velocity at low water velocities of about 0.5 m/sec. Lower air velocities around 10% of the water velocity were observed in the second sewer at water velocities around 1 m/sec.

More extensive testing in the third sewer indicated that air velocities were not influenced by wind speed or the temperature difference between sewer and ambient air. In this case, the principal factor determining air flow rates was the position of adjustable vents in ventilation structures. Adjustment of the position of these vents caused a threefold variation in ventilation rates.

The general conclusion arising from the work was that ventilation rates in free convection sewers are determined primarily by the characteristics of ventilation control structures. This observation complicates development of general guidelines but a rule of thumb based on the present study is that air velocities in sewers without forced ventilation range between 10% and 50% of the water velocity.

3. Estimation of ventilation rates in gravity sewers with no forced convection

The present study adopted a sewer ventilation model proposed earlier by Apgar et al (2009). The model is based on a force balance over the air space in the sewer. This force balance assumes that the rate of change in air momentum between two locations is given by the sum of the:

- Pressure force arising because of longitudinal changes in head space pressure and
- Drag force due to drag at the air/water interface and
- Friction force at the air/sewer interface.

The analysis adapts existing correlations based on pipe flow to estimate the drag and friction force terms.

The analysis has been consolidated into an excel spreadsheet and a User Manual. The spreadsheet assumes the sewer comprises a number of ‘reaches’ which span between ‘nodes’. A reach is a length of sewer pipe of constant diameter and slope and a node is a point where there is either a ventilation structure or an interconnecting sewer.

The model requires the user to input data about air conditions (e.g. temperature and humidity), wind conditions, sewer characteristics and sewage flow rate. The calculated output in the absence of a fan is a set of values for the expected air flow rate in each reach and the absolute air pressure at each node. In the case where a ventilation fan is included, the spreadsheet requires the user to enter an expected fan pressure. The tool will then determine the air flow rate in each reach and the absolute air pressure at each node. A trial and error method is required to match the estimated air flow rate through the fan to the fan curve.

The reliability of the calculation tool was determined by comparing estimated node pressures and air flow rates with values measured in a single gravity sewer operating without a forced ventilation system. The node pressure scattered around the measured values by plus or minus 30% and the air velocities differed from measured values by plus or minus 50%.

4. Ventilation rates through a drop structure

The study developed a theoretical description of the expected concentration of a tracer gas in the gas space within a drop structure following injection of a single pulse of tracer into the upstream air flow. The model was based on the assumption that the gas space was well mixed. The outcome was that the change in tracer concentration was expected to decline exponentially with time following injection of the tracer pulse with an exponent dependent on the ventilation rate through the structure.

The reliability of the model was evaluated using carbon monoxide as a tracer during tests conducted on a single drop structure in a gravity sewer operating without forced ventilation. The results showed the expected exponential relationship between tracer concentration and time following injection of a single tracer pulse. The consequent estimate of the air velocity in the downstream sewer was about 10% of the water velocity.

The general conclusion is that the transient tracer test method and the analysis based on the well mixed gas space model provide a reliable approach to determining ventilation rates through existing drop structures. However further tests are required on other drop structures to develop useful rules of thumb for predictive use.