ENERGY LOSSES AND PRESSURE HEAD CHANGES AT STORM DRAIN JUNCTIONS

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STATEMENT

I hereby declare that the content of this thesis does not comprise in the main any work or material which I have previously submitted for a degree or other similar award from any other Institute of Technology or University.

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ABSTRACT

An investigation has been made of the magnitude of hydraulic losses produced by storm drain junction structures which connect pipes operating under flow-full conditions.

The study comprised three parts:

(a) a literature review;

(b) a study of losses associated with commercially available 'closed' pipe junctions;

(c) an experimental study, using hydraulic models, to investigate the magnitude of losses at 'open' pit structures.

A theoretical analysis was developed for closed pipe junctions. The theory was found to be adequate when checked against available experimental data. For pit junction structures, the experimental programme comprised thirty models covering an extensive range of geometric and hydraulic variables. The model studies indicated that maximum hydraulic efficiency is attained when the junction branch point is located on the downstream face of the pit. Data have been plotted for bend deflections angles of between 0^0 and 90^0, and for upstream to downstream pipe diameter ratios within the range 0.55 to 1.00. Grate inlet flow and submergence have been identified as parameters affecting losses. Semi-empirical equations have been developed to account for junction losses when the branch point is located on the downstream face of the pit.

Nomenclature

The symbols used in this thesis are listed hereunder. Alphabetical subscripts have been used which conform to a standard format. The subscript 'u' refers to the primary upstream pipe. If more than one upstream pipe converges at a junction, the second such pipe is characterized by the subscript 'b' (branch or lateral pipe). The outfall pipe is identified by the subscript 'o'.

Notation

a spacer length for compound mitre bend junction.

A_b mean cross sectional area of the lateral pipe.

A_m mean cross section area of the model pipeline.

A_o mean cross sectional area of the outfall pipe.

A_p mean cross sectional area of the prototype pipeline.

A_r model-prototype area ratio.

A_u mean cross sectional area of the upstream pipe.

B pit dimension (square in plan).

C_b dimensionless total energy loss coefficient as defined by the difference between the lateral total energy line elevation and the downstream total energy line elevation when extrapolated linearly to the branch point of the junction, divided by the average downstream velocity head.

C_u dimensionless total energy loss coefficient as defined by the difference between the upstream total energy line elevation and the downstream total energy line elevation when extrapolated linearly to the branch point of the junction, divided by the average downstream velocity head.

D_b mean diameter of the lateral pipe.

D_m mean diameter of the model pipeline.

D_o mean diameter of the outfall pipe.

D_p mean diameter of the prototype pipeline.

D_r model-prototype diameter ratio.

F_o Froude number in the outfall pipe.

g acceleration due to gravity (9.81 m/s^2).

HGL Hydraulic Grade Line (or pressure line or piezometric head line).

k_b dimensionless pressure head change coefficient as defined by the difference between the lateral and downstream pressure line elevations when extrapolated linearly to the branch point of the junction, divided by the average downstream velocity head.

k_u dimensionless pressure head change coefficient as defined by the difference between the upstream and downstream pressure line elevations when extrapolated linearly to the branch point of the junction, divided by the average downstream velocity head.

k_w dimensionless pressure head change coefficient as defined by the difference between the water surface elevation in a pit junction and the elevation of the downstream pressure line when extrapolated linearly to the branch point of the junction, divided by the average downstream velocity head.

L_m characteristic length in a model.

L_p characteristic length in a prototype.

L_r scalar ratio of the model equal to the characteristic length of the model divided by the characteristic length of the prototype.

p_b static pressure in the lateral conduit.

p_o static pressure in the main conduit.

p_u static pressure in the upstream conduit.

Q_b mean discharge in the lateral pipe.

Q_g mean grate flow discharge through the pit grate inlet

Q_m mean discharge in the model pipeline.

Q_o mean discharge in the outfall pipe.

Q_p mean discharge in the prototype pipeline.

Q_r model-prototype discharge ratio.

Q_u mean discharge in the upstream pipe.

R_x resultant force component acting at the junction used in the impulse-momentum equation.

S depth of water in a pit junction measured from pit invert elevation to water surface elevation (submergence).

TEL Total Energy Line.

V_b mean velocity in the lateral pipe.
V_m mean velocity in the model pipeline.
V_o mean velocity in the outfall pipe.
V_p mean velocity in the prototype pipeline.
V_r characteristic model-prototype velocity ratio.
V_u mean velocity in the upstream pipe.
WSE pressure head change defining the difference between the water surface elevation in a junction pit and the elevation of the downstream pressure line when extrapolated linearly to the branch point of the junction.
γ specific weight of a fluid.
ΔH available head.
ΔH_b total energy loss across a junction as defined by the difference between the lateral total energy line elevation and the downstream total energy line elevation when extrapolated linearly to the branch point of the junction.
ΔH_u total energy loss across a junction as defined by the difference between the upstream total energy line elevation and the downstream total energy line elevation when extrapolated linearly to the branch point of the junction.
Δk_p incremental pressure head change coefficient due to presence of a pit structure, over and above a theoretical solution
Δk_s incremental pressure head change coefficient due to submergence effects, over and above a theoretical solution
$\frac{\Delta P}{\gamma}$ change in pressure head as defined by the difference between an upstream pressure line elevation and the downstream pressure line elevation when extrapolated linearly to the branch point of the junction.
ρ density of water ($\approx$ 1000 kg/m^3).
θ_b angle of lateral pipe deflection.
θ_u angle of upstream pipe deflection.