BASIC STREET CANYON MODEL

CERC

In this document 'ADMS' refers to ADMS-Roads 5.0, ADMS-Urban 5.0 and ADMS-Airport 5.0. Where information refers to a subset of the listed models, the model name is given in full.

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1. INTRODUCTION

The basic street canyon model which is incorporated into ADMS is based on the Danish model OSPM. OSPM (Operational Street Pollution Model) was developed at the Danish National Environmental Research Institute (NERI), is described in a series of papers [1,2,3,4] and has been validated by NERI using Danish and Norwegian data.

The basic canyon model is used for calculating the concentration at points which lie in roads lined with buildings with heights greater than 0.5 m. Concentrations inside the road tend to the non-canyon results in the limits as the canyon height is reduced to zero or as the ratio of canyon height to road width decreases to zero. Concentrations at points outside the canyon are identical with those that would be obtained if the road were not a canyon.

ADMS also has an advanced street canyon model which addresses some of the limitations inherent in the basic street canyon model. The advanced street canyon model calculates the dispersion of pollutants within and outside of the street canyon. The advanced street canyon model also allows for the properties of the street canyon, e.g. building height, to be different on the two sides of the canyon, for the presence of pavements within the canyon and for the transport of material between neighbouring street canyons. For more details on the advanced street canyon model refer to Technical Specification document P28/02.

2. CANYON GEOMETRY

The model ignores end effects such as junctions. It assumes a straight length of road which has a width L, and is lined, continuously on both sides by flat-roofed buildings of height H_B, Figure 1.

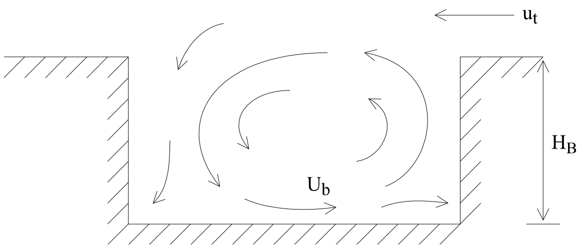

Figure 1 Roof level and street level winds in a street canyon

3. RECIRCULATION REGION

Figure 1 shows how, when the wind blows perpendicular to the axis of the street, a vortex is generated in the street canyon. The region occupied by the vortex is called the recirculation region and the velocity at street level in the recirculation region, u_b, is opposite in direction to the velocity at roof level u_t. A vortex will be generated if the roof level wind is not parallel to the street's axis i.e. if there is a component of the wind perpendicular to the street. Figure 2 shows the general case of a wind at an angle ϕ to the street axis.

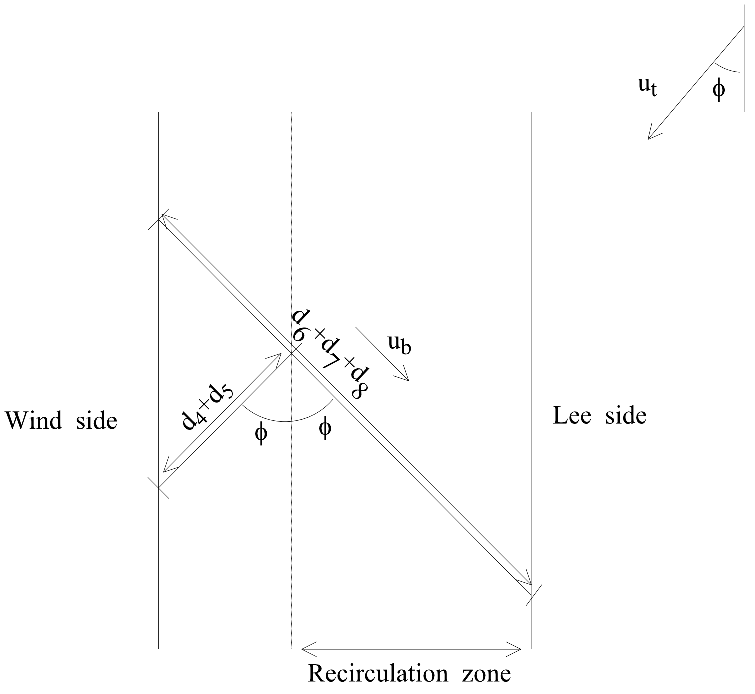

Figure 2 Oblique wind

The assumed structure inside the canyon that has a recirculation region on the lee side of the street and no vortex on the windward side is illustrated in Figure 3.

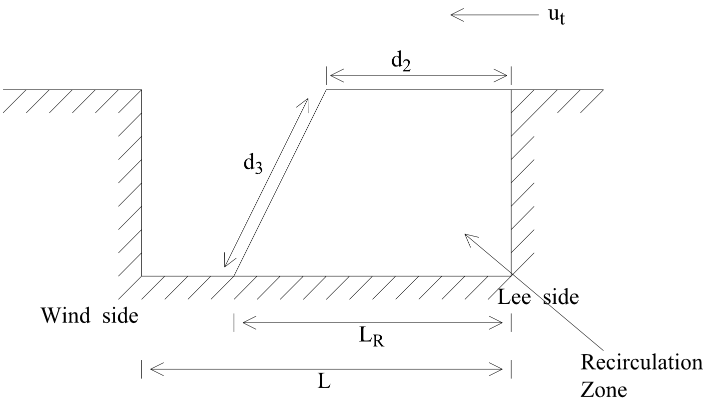

Figure 3 Recirculation zone formed on lee side of street (wind direction perpendicular to the street axis)

The width of the recirculation region, L_R, is calculated as in the OSPM model. L_R is a function of roof level wind speed and canyon height.

$$L_R = 2rH_B$$

where

$$\begin{aligned} r &= 1 && \text{for } u_t \geq 2 \text{ m/s} \\ &= u_t - 1 && \text{for } 1 < u_t < 2 \text{ m/s} \\ &= 0 && \text{for } u_t \leq 2 \text{m/s} \end{aligned}$$

4. CONCENTRATIONS

The concentration in the recirculation region, C_R, is determined from a balance of inflow and outflow of material. The inflow, Q_{IN}, is due to the vehicles in the recirculation region.

$$Q_{IN} = \frac{Q}{L} d_1$$

where

$$L_{\max} = L/\sin\phi$$
$$d_1 = \min(L_{\max}, L_R)$$

The outflow, Q_{OUT}, is across the top of the recirculation region which has length d_2

$$d_2 = Min(L_{\max}, 0.5L_R)$$

and across the side length of d_3

$$d_3 = Max\left(0, \left(2\frac{d_1}{L_R} - 1\right)L_S\right)$$

giving

$$Q_{\mathrm{OUT}} = C_R\left(v_d d_2 + \sigma_w d_3\right)$$

where v_d is the removal velocity at roof level given by

$$v_d = \left(.01\ u_t^2 + 0.4\ \sigma_{w_0}^2 \right)^{1/2}$$

and σ_w is the street level turbulence given by

$$\sigma_w = \left(u_b^2 + \sigma_{w_0}^2 \right)^{1/2}$$

σ_{w0} is the traffic induced turbulence (see section 5). Balancing the inflow and outflow of material gives the cavity concentration

$$C_R = \frac{(Q/L)\ d_1\ \sin\phi}{v_d\ d_2 + \sigma_w\ d_3}$$

The concentration at a point on the lee side of the canyon is given by the sum of C_R and a "direct" contribution, $C_{D\mathrm{Lee}}$, obtained by integrating across the recirculation region.

$$\mathrm{C}_{\mathrm{D_{Lee}}} = \sqrt{\frac{2}{\pi}}\ \frac{\mathrm{Q}}{\mathrm{L}\sigma_{\mathrm{w}}}\ \Big\{\ \ln\left[\frac{\mathrm{h_0} + \sigma_{\mathrm{w}}\,\mathrm{d_1}/\mathrm{u_b}}{\mathrm{h_0}}\right]$$

$$+ \mathrm{R}\ln\left[\frac{\mathrm{h_0} + \sigma_{\mathrm{w}}\,\mathrm{d_6}/\mathrm{u_b}}{\mathrm{h_0} + \sigma_{\mathrm{w}}\,\mathrm{d_1}/\mathrm{u_b}}\right]$$

$$+ \frac{\sigma_{\mathrm{w}}}{\mathrm{v_d}}\left[\ 1 - \exp\left[\frac{-\mathrm{v_d}(\mathrm{d_7} + \mathrm{Rd_8})}{\mathrm{u_b}\,\mathrm{H_B}}\right]\right]\ \Big\}$$

where

$$d_1 = Min(\min(L_{\max}, L_R), x_1)$$
$$d_6 = \mathrm{Min}\ (\mathrm{L_{Max}}, \mathrm{x_1})$$
$$d_7 = \mathrm{Max}(\min(\mathrm{L_{Max}}, L_R),\ \mathrm{x_1}) - \mathrm{x_1}$$
$$d_8 = \max(L_{\max}, x_1) - x_1 - d_7$$
$$x_1 = \mathrm{u_b}\ (\mathrm{H}_B - \min(H_B, \mathrm{h_0}))/\sigma_{\mathrm{w}}$$

x_1 is the downstream distance from a source element at which $\sigma_z = H_B$, when the plume is assumed to escape from the canyon.

$$C_{canyon} = C_{D_{Lee}} + C_R \qquad \text{on the lee side}$$

At points on the wind side of the canyon the concentration is just by the “direct” contribution, $C_{D\mathrm{Wind}}$, from vehicles outside the recirculation region. This is given by

$$C_{D_{\mathrm{Wind}}} = \sqrt{\frac{2}{\pi}}\,\frac{\mathrm{Q}}{\mathrm{L}\,\sigma_{\mathrm{w}}}\left\{ \ln\left(\frac{\mathrm{h}_0 + \sigma_{\mathrm{w}}\ \mathrm{d}_4 / \mathrm{u}_{\mathrm{b}}}{\mathrm{h}_0} \right) + \frac{\sigma_{\mathrm{w}}}{\mathrm{v}_{\mathrm{d}}}\left(1 - \exp\left(- \frac{\mathrm{v}_{\mathrm{d}}\ \mathrm{d}_5}{\mathrm{u}_{\mathrm{b}}\ \mathrm{H}_{\mathrm{B}}} \right) \right) \right\}$$

where $d_4 = Min\left(\left(L_{\max} - L_R\right),\quad x_1\right)$
$d_5 = Max\left(\left(L_{\max} - L_R\right), x_1\right) - x_1$

and h_0 is the initial vertical spread due to the vehicles, which is taken to be 1m.

$$C_{canyon} = C_{D_{Wind}} \qquad \text{on the wind side}$$

The concentration in a street canyon, $C_{street\ canyon}$, is then the sum of the canyon concentration C_{canyon} described above and the non-canyon concentration $C_{non\text{-}canyon}$, weight according to the ratio of H_B/L.

$$C_{streetcanyon} = C_{canyon}(Sratio) + C_{non-canyon}(1 - Sratio)$$

where $Sratio = Min\left(\left(1 + 3\sin^2\phi\right)\left(\frac{H_B}{L}\right)^2, 1\right)$

5. VEHICLE INDUCED TURBULENCE

The vehicle-induced turbulence, σ_{w_0}, has been determined experimentally. It is given by

$$\sigma_{v_{vehicle}} = b \cdot \left(\frac{\sum_i^{n_c} NN_i V_i S_i^2}{L} \right)^{1/2}$$

where $b = 0.12$ and n_c is the number of vehicle categories. For each vehicle category the number of vehicles passing a point in the street each second, NN, the vehicles’ average speed, V, and the horizontal area occupied by each vehicle, S^2, are known.

REFERENCES

[1] Hertel, O. and Berkowicz, R., 1989. ‘Modelling pollution from traffic in a street canyon. Evaluation of data and model development.’ *DMU Luft A-129*.

[2] Hertel, O. and Berkowicz, R., 1989. ‘Modelling NO_2 concentrations in a street canyon.’ *DMU Luft A-131*.

[3] Hertel, O., Berkowicz, R. and Larssen, S., 1990. ‘The Operational Street Pollution Model (OSPM).’ *18th International meeting of NATO/CCMS on Air Pollution Modelling and its Application*. Vancouver, Canada, 1990. pp741-749.

[4] Hertel, O. and Berkowicz, R., 1989. ‘Operational Street Pollution Model (OSPM).’ Evaluation of the model on data from St Olavs Street in Oslo. *DMU Luft A-135*.