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NATURAL VENTILATION OF PARKING GARAGES

(Ventilation naturelle de parcs de stationnement)

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SUMMARY

Parking garages having a width exceeding b = 54 m are usually equipped with means for mechanical ventilation. This may give rise to very high energy demands.
A combination of a wind-tunnel investigation and a mathematical simulation technique conducted on models of a partly two-storey parking garage (b ≅ 100 m) situated beneath a large block of buildings consisting of houses, shopping center and offices shows that wind penetrating the partly open garage façades can provide sufficient ventilation.
Effects on ventilation of varying the open area of the façades and of fitting openings - vides - in the garage roofs were studied. The effect of such ventilation means on air quality close to buildings - balconies etc. - was also measured.

sufficient ventilation by making openings in walls and roof of the garage through which the wind can pass.
However, ventilating the garage in this way may not give rise to unacceptable high exhaust gas concentrations near the buildings on top of the parking garage.

On the instructions of Bredero Vastgoed N.V. a wind tunnel study has been conducted to establish what provisions have to be made to obtain a sufficient natural ventilation of the parking garage under all practical conditions of wind and garage use. Garage air change rates were computed for several opening configurations of garage walls and roof, from wind pressures measured on a 1:300 model, of the city subcenter.
Concentrations of exhaust gases released in the garage were measured mainly at a height corresponding to 2 m full scale in front of the buildings, using SF-6 as a tracer gas.
The wind tunnel measurements of pressures and outdoor CO-concentrations were carried out by MT-TNO, Apeldoorn, and the computations relating to the mathematical ventilation model of the garage, by IMG-TNO, Delft.

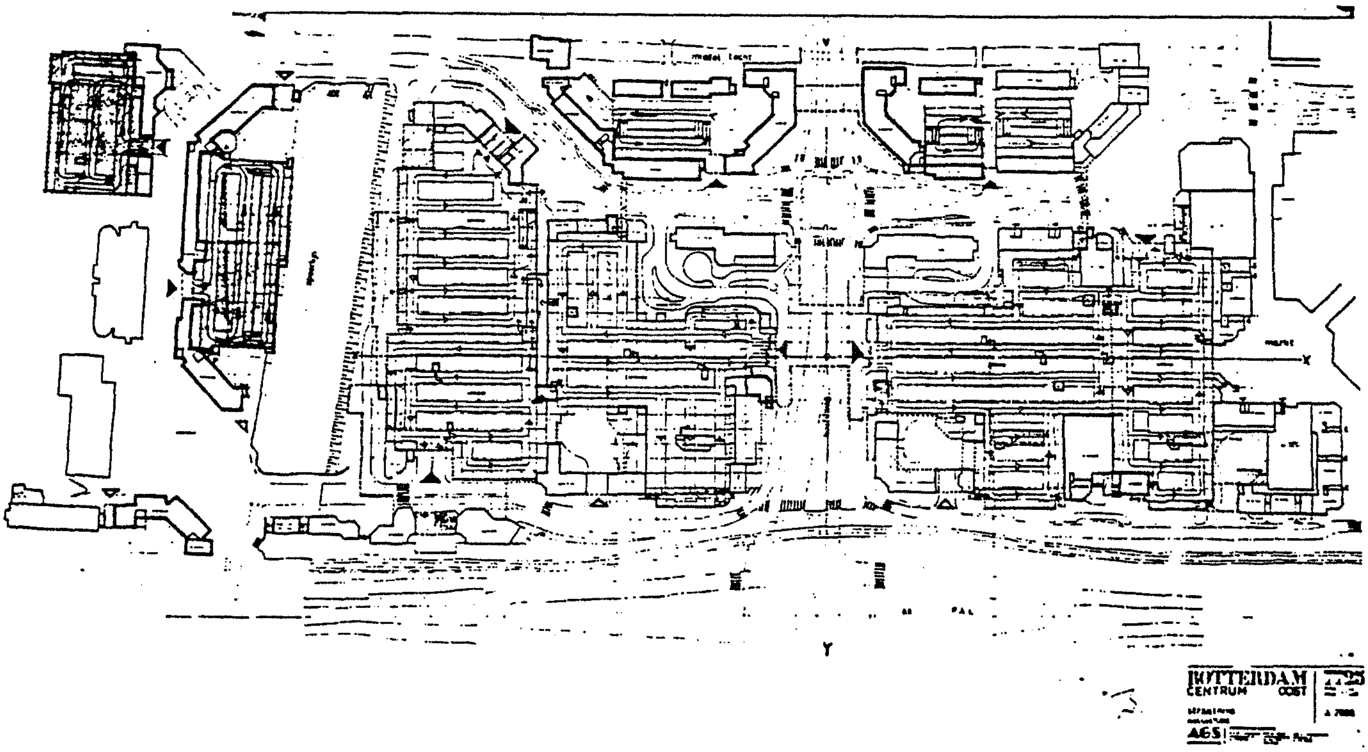


Fig. 2 Ground-plan of parking garage

As an input to this mathematical model the wind pressures on the garage giving the actuating force for ventilation must be known. These were measured on a closed model, i.e. with openings like entrances and vides being omitted.
This is justified by the fact that the air-flow rate through the garage is relatively small, so that the external pressure distribution will not be influenced significantly.
The pressures were measured at small openings in the garage façades and roof. As a reference pressure the static pressure in the wind tunnel upstream of the model, was used.
The SF_6 tracer gas was emitted from two line-sources simulating files of motorcars waiting with running motors at the garage exits (sit. A) and an emission source close to a vide (sit. B) in an open parking garage.
This method seems to be in conflict with what has been put forward concerning the flow through the garage on model scale. The effect of air velocities inside the garage on CO-dispersion outside the garage is expected to be small, however, as the high velocities outside the building will strongly dominate. An other method would have been to release tracer gas just outside the garage openings in a quantity to be deduced from computed ventilation rates and the maximum tolerable emission in the parking garage.
Concerning the method followed for "de Oosterhof" it can be said that the measured concentrations may be somewhat overestimated.

2.2 The mathematical flow model

The pressure drop (Δp) over a ventilation provision causes an air flow (q_v) depending on the resistance of the ventilation provision. The net air flow to or from one place divided by the volume of the place(V) gives a certain air change rate (a), in formula:

$$a = \frac{\Sigma\, q_v \text{ incoming}}{V} \qquad (1)$$

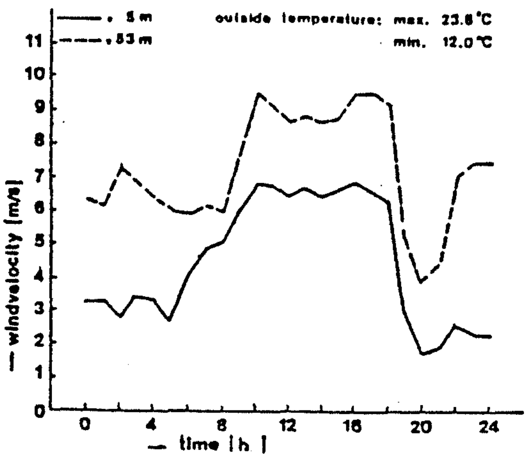
Due to the fact that houses are planned on top of the garage,the air leaving the garage may give a maximum CO-concentration in the air around the houses of 35×10^{-6} m^3/m^3 (35 ppm).

3.2 The source of pollution inside the garage

The air pollution depends on the following facts:

- number of cars with running engines
- type of engine (type of fuel, cylinder volume, two- or four-stroke)
- condition of the engine (tuning up of fuel and ignition)
- number of revolutions of the engines
- time of stay in the garage
- cold or hot engine
- acceleration or constant number of revolutions (speed)

It is very difficult therefore to establish the extent of the pollution at different times of the day.
Mercey (ref. 4) gives an approximation of the extent of the pollution based upon the maximum number of cars to be parked in the garage, the average type of car used in Western-europe and the type of use of the garage.
For the type of use of the garage there is a difference to be made between a parking garage for people working in offices near the garage and people living and shopping near the garage.
Because of the size of the "Oosterhof" garage (the southern part has 650 parking places) and the presence of both dwellings, shops and offices near the garage it is assumed that the garage will be used by both groups in the same way.
According to the approximation by Mercey an exceptional situation is chosen in which 250 cars leave the southern part of the garage during half an hour. Their average stay with running engine inside the garage is chosen at two minutes.



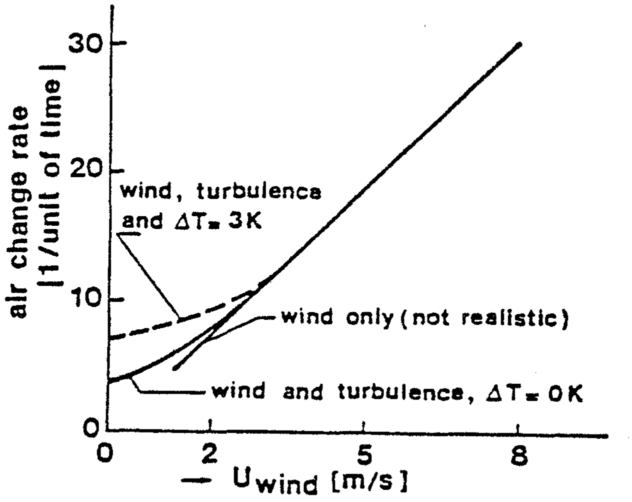


Fig. 4 Daily course of the wind velocity on different heights (ref. 6).

Fig. 5 Wind, turbulence and temperature effect on air change rate.

- Temperature differences between inside and outside of the garage will be generated by solar radiation, heat loss of houses, shops and offices above the garage and production of heat by the engines of the cars, by the ligthing and by people. Moreover, the accumulation of the building mass will ensure the generation of small temperature differences for most of the time.
- Turbulating air will cause limited ventilation, even at zero wind velocity and zero temperature difference. According to ref. 7 measurements on open windows show average wind velocities in the openings of 0,10 to 0,15 m/s at zero wind velocity and temperature difference.

Combination of the effects mentioned above will lead to ventilation curves as shown in fig.5. The air change rate (a) always has a certain minimum value, which will be about half the air-change rate caused by a wind velocity of only 2 m/s.

In most cases ventilation provisions can be based on a wind velocity of 2 m/s, and if necessary, on a frequently occurring temperature difference.

4.2 Calculated ventilation

For a wind velocity of 2 m/s the four main wind directions and opening sizes and an opening configuration given by the architect of Bredero Vastgoed N.V. the air-change rates have been calculated. Depending on these results calculations have been carried out on other opening configurations and other opening sizes giving better results on both ventilation, construction and architecture. This leads to a definitive opening configuration and opening sizes by which the calculated air-change rates amply fulfil the starting requirements.

As an example the southern part of the garage with definitive opening configuration and opening sizes is shown in figure 7. Also shown are the calculated flows through the openings caused by wind from direction south and a velocity of 2 m/s.

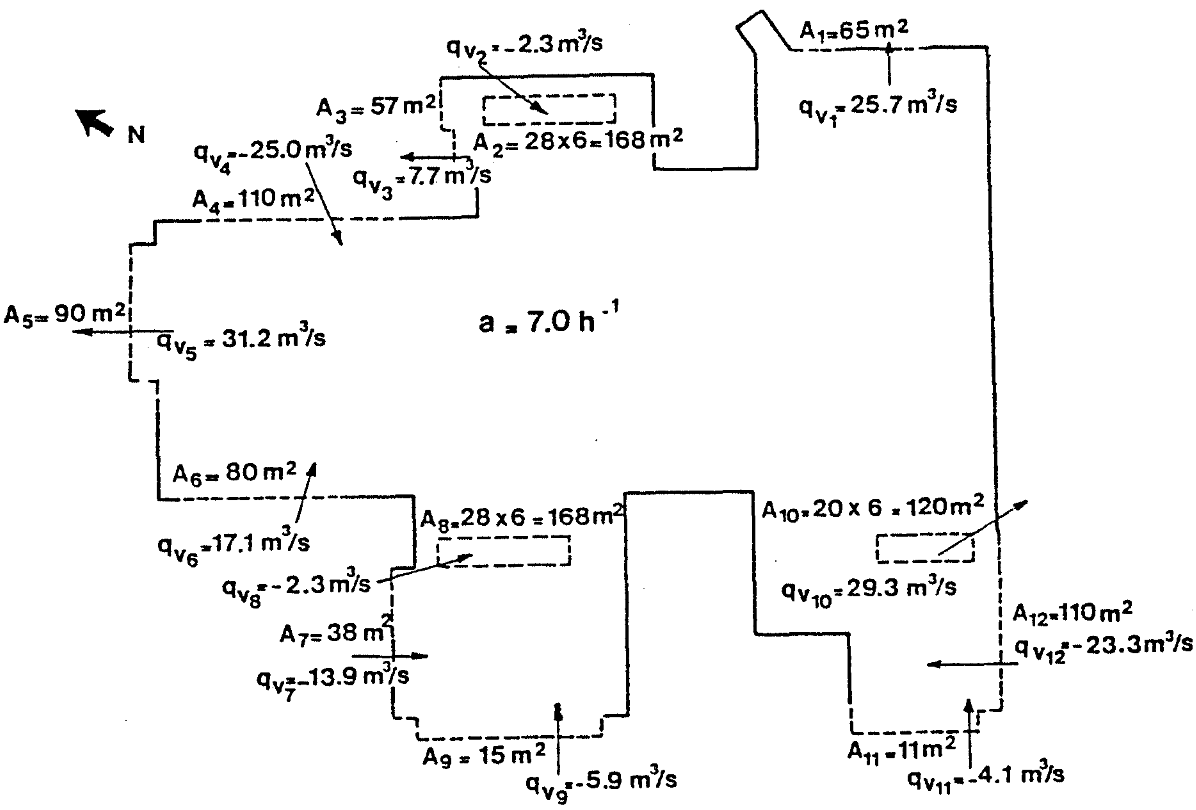


Figure 7 Diagram of the southern part of the parking garage with openings (A_1 - A_{12}) in the definite situation and flows caused by wind direction south and velocity 2 m/s.

4.3 CO-concentrations outside the garage

Situation A: files of motorcars near the garage exits

It appears from concentration measurements that the shopping street running North-South remains totally free from exhaust gases leaving the garage.
As might be expected, the concentration of gases is highest in front of the exits (23 ppm, figure 8).

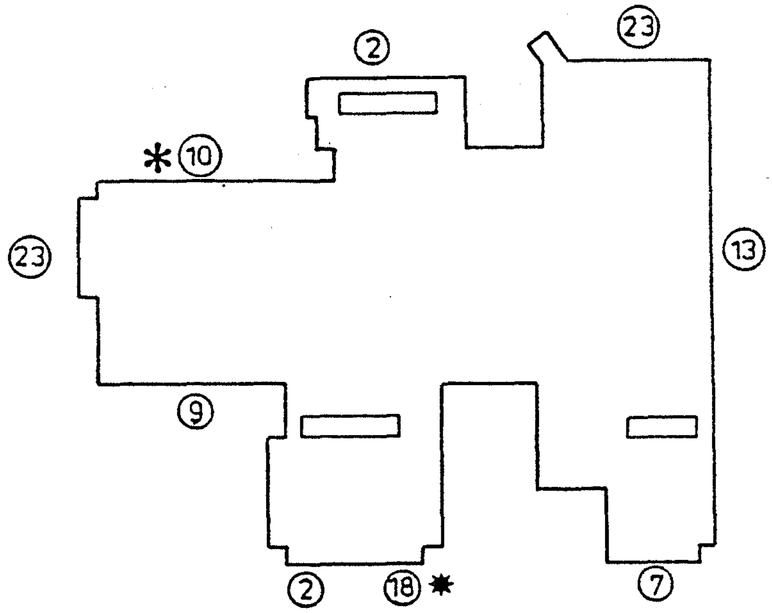


Fig.8 CO-concentrations outside the parking garage.

The effect of extending the garage beneath a building block by 9 m (meas. stat. *) appears to give a decrease in gas concentration from 10 to 3 ppm. Thus, by causing the parking garage to protrude in front of the buildings, nuisance from exhaust gases near the buildings could be avoided.
The concentration decreases rapidly with height, as was established for the arbitrarily chosen measuring station *. In this case the concentration decreased from 18 ppm at 2 m, to 3 ppm at 12 m height. A uniform distribution of wall openings will give the lowest outdoor concentrations of garage gases.

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