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Pressure Simulation Program

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PRESSURE SIMULATION PROGRAM

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SYNOPSIS

A computer program has been developed to predict the wind pressure coefficients C_p on facades and roofs of block shaped buildings.
The program is based on fits of measured data, including wind shielding by obstacles and terrain roughness.

Main advantages of the program are:

- it needs no expertise of its users on wind pressures;
- the input is simple. It exists of building and obstacles coordinates and orientations;
- generating C_p values for ventilation model calculations needs no separate action. By linking the pressure simulation program and the ventilation calculation program as well as their input, wider application of ventilation programs for non-experts becomes possible.

The accuracy of the predicted wind pressures in the first version of the pressure simulation program are promising. Especially complex building shapes and surroundings have to be dealt with more carefully, as well as increasing wind velocities in small passages. Also detailed improvements are necessary, e.g. to account for sloped roofs and the position of ventilation provisions above roof level.
Therefore, generation and implementation of additional wind tunnel data is planned, to improve the present version.

1. INTRODUCTION

A good prediction of wind pressure coefficients C_p, on facades and roofs with ventilation provisions, is vital for natural ventilation calculations. The accuracy of the ventilation calculations can highly depend on it, if wind is the dominant driving force.
The use of wind tunnel experiments to predict C_p-values is a proven, but expensive method. The use of C_p-estimations from data bases is a cheaper, but less accurate alternative and in case of surrounding obstacles almost impossible.
In both methods, generating C_p-values is an expert job, to be performed separately, primary to the actual ventilation calculations. This is found a disadvantage for operating applications with ventilation models by non-expert users.

The organisation for applied scientific research TNO is developing an automatic control system for natural ventilation of industrial buildings for the dutch ventilation company BRAKEL-ATMOS. The control system calculates and sets optimum grill positions, depending on meteo conditions, inside temperature, required ventilation flow and allowable draught.
For this application the need for implicit prediction of wind pressure coefficients became urgent. Due to the knowledge of most its users, the input needs to be simple data of the building to be ventilated and its surroundings.
The lack of such a tool lead to the development of the first version of a wind pressure simulation program, described in this paper.

The pressure simulation program is a computer program, written in Pascal and running under MS-DOS.
The pressure simulation program may be applied for:
- simple building structures (to be simplified to rectangular shaped facades with flat roofs);
- with ventilation provisions on variable positions within the facades and roof;
- in different surroundings per orientation;
- with common terrain roughnesses (z_0 = 0.35 to 7 m);
- and several local obstacles (also more or less block shaped).

2. BASICS OF THE PROGRAM

The pressure simulation program is based on measured data [1, 2]. It concerns wind tunnel experiments:
- on typical block shaped buildings,
- in different terrain roughnesses,
- with and without obstacles on systematically varying distances.

Because of the systematic set-up of these measurements, it was possible to fit the data by a set of mathematical expressions. For parameters describing the data additional references [3, 4 and 5] are applied.

The start of the fits is a formula, describing the general relation of wind pressure and wind direction for an unshielded object. This relation is presented by different researchers (Phaff

[1], Walker and Wilson [4] and ASHRAE).
With a set of additional formulas, containing the building dimensions and the terrain roughness as relevant parameters, the wind pressures on different spots of the roof and each facade are predicted.

The next stage was to add the influence of nearby obstacles.
For the main orientation of each obstacle to the building, a correction on the unshielded C_p was determined, using both the distance between obstacle and building and the leeward side C_p of the obstacle itself. The obstacle leeward C_p was calculated using the same procedure as used for the unshielded building, but now using of course the obstacle dimensions.
After calculating the C_p correction for the main obstacle direction, the correction for surrounding directions is determined, using the "shielding angle" of the obstacle to the building.

To ease the use of the program, a set of formulas has been added, calculating input parameters like dimensions and angles from a minimum of building and obstacle coordinates, to be entered by the user.

3. PROGRAM INPUT

To allow the program to be used by non-experts, the input is restricted to measurable dimensions of the building, nearby obstacles and their positions.

To prevent a time consuming, too detailed input, a simple instruction points out what kind of details are relevant. An example is the criteria for obstacles further away than 5 x their height. These are not considered to be of importance for the local shielding but may contribute to the terrain roughness.

An example of a part of the input is given in the text block and the building lay-out (figure 1).

```
 obstacles(position in m(=meter))

terrain level above sea     : 0
roof height of the building: 8.2

    name: HOUSE
     x,y:  0,  0
  azimut:  270
   l,b,z:  22.6 8.5 8  {actual gutter
height=5.4}

    name:
     x,y:  20, -10
  azimut:  0
   l,b,z:  0.1, 0.1, 10

    name:
     x,y:  14.6, 0
  azimut:  270
   l,b,z:  22.6, 2.15, 3

    name:
     x,y:  18.3 ,0
  azimut:  270
   l,b,z:  8.5 34.2 8.5
```

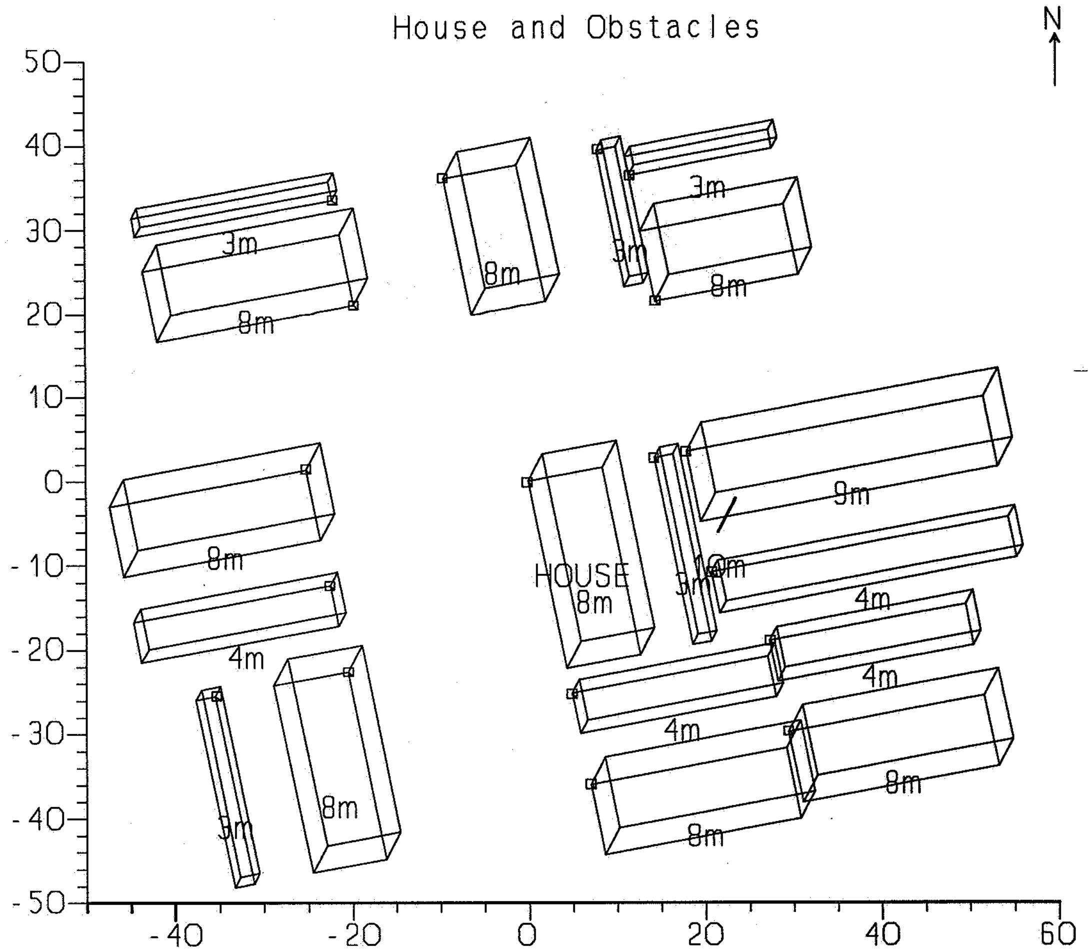


Figure 1 *Input lay-out with a marked edge on floor level of each building. Turning left first defines dimension x and secondly y. Azimuth is given for the first facade.*

4. PROGRAM OUTPUT

The output of the pressure simulation program is an array of pressure data. The pressure data files may be linked directly to a ventilation calculation program.

The output also may be expressed graphical. An example of a graphical output is given in figure 2.
The upper figures show the C_p-values per wind direction in the unshielded situation (imaginary), the local shielding correction (black filling) and their combined result, presenting the actual C_p-values. In the lower figures C_p is plotted polar on a map with the building lay-out. From this plot the influence of each obstacle on C_p may be seen directly.

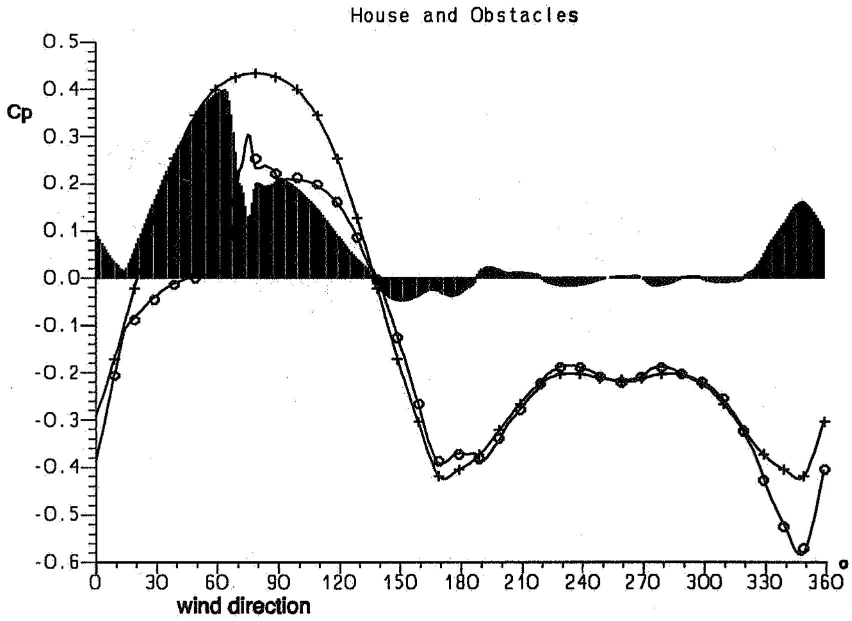
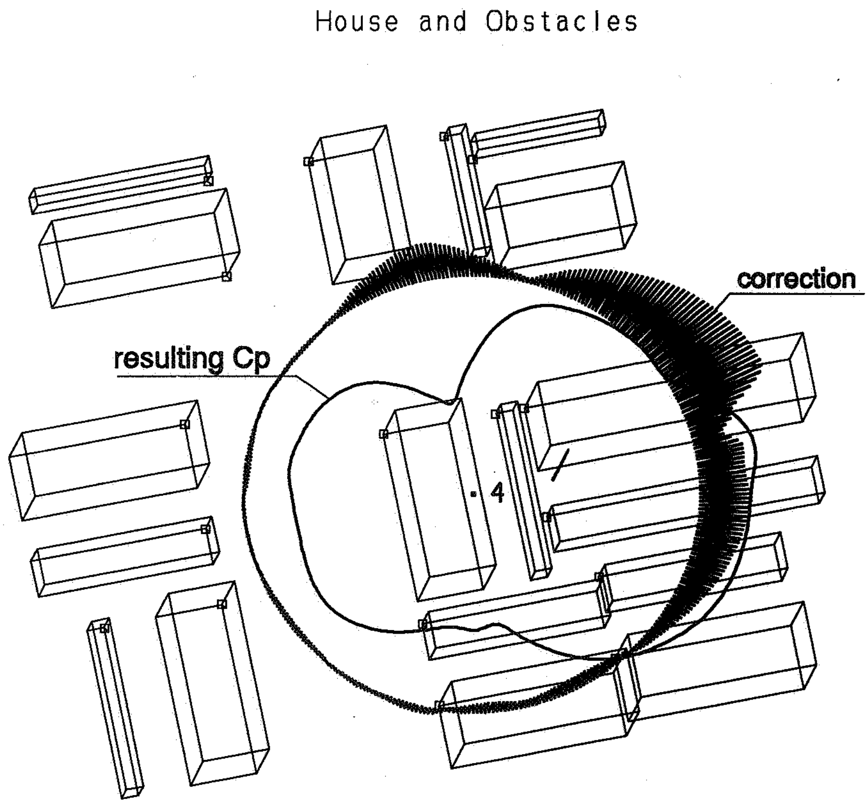


Figure 2 *Output graph for the rear facade. '+'= unshielded, Bar=obstacle correction 'o'= resulting C_p. Below given as a polar diagram.*



5. FIRST EVALUATION

For the output example shown, a data set of wind-tunnel C_p-values is available. The data set has proved to fit well with actual on-site measurements.
A comparison of these data and the C_p-values calculated with the pressure simulation program is presented in figures 3, 4 and 5.

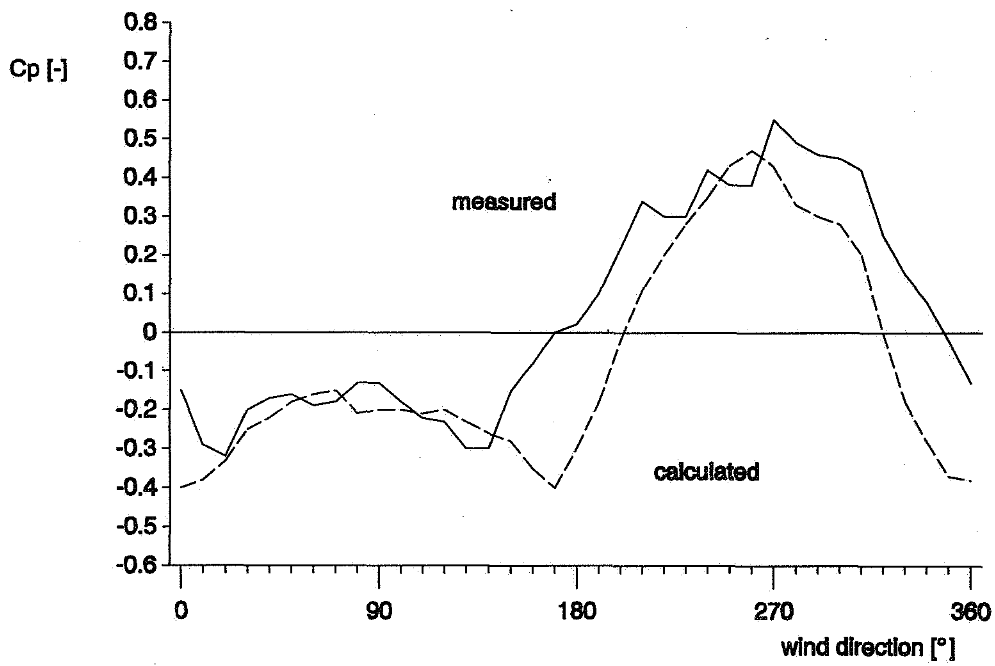


Figure 4 *Comparison measured and calculated C_p for the front facade*

The comparison shows a rather good agreement for both facades. Most remarkable in these characteristics is the change of calculated windward into leeward pressures happening too fast. An over-estimation of the contraction effect (under-estimation of the velocity increase) in case of small passages is held responsible for this.

The comparison for the roof pressure shows a worse agreement, especially for wind directions between 180° and 330°. The slope of the roof and the position of the ventilation duct within the roof is held responsible for this difference. The pressure simulation program doesn't account for sloped roofs yet.

One should realise that a rather preliminary tool is used and that a rather complex configuration of obstacles is concerned.

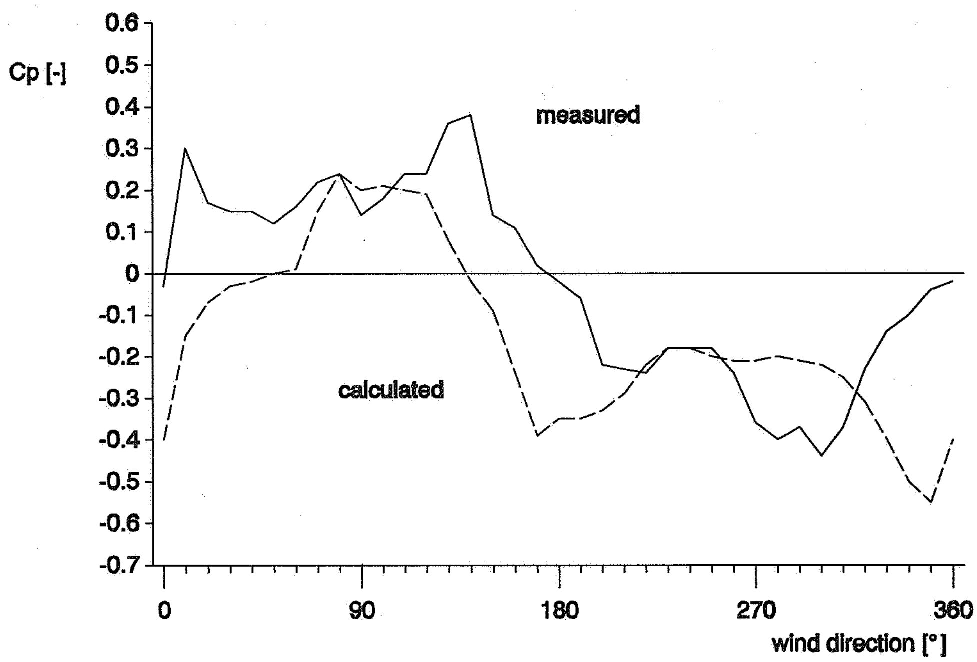


Figure 5 *Comparison measured and calculated C_p for the rear facade*

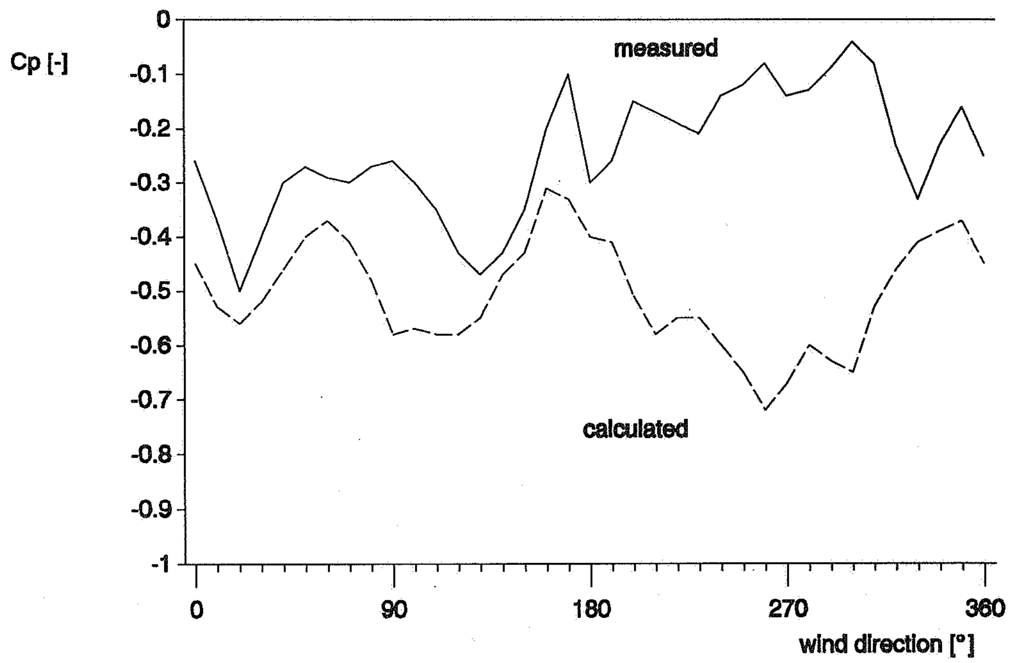


Figure 6 *Comparison measured and calculated C_p for the roof pitch*

Also, one should realise that minor differences in Cp, especially over a wind direction sector, and at steep changes, will have less effect in reality. This is due to normal fluctuations of the actual wind direction.

Therefore the results of the comparison are considered to be hopeful. If some essential corrections are added, the pressure simulation program is expected to be a useful tool. Hence, further development of the tool is recommended.

6. FUTURE IMPROVEMENTS

To end up with a useful and sufficient accurate pressure simulation program, improvements are recommended on:

- complex building shapes (non-block shaped, like sloped roofs, building extensions or combined blocks);
- complex surroundings (obstacle extensions or combined obstacles, sloped surfaces, seasonal corrections for vegetation);
- contraction effects depending on passage width.

Apart from this, extracting a version for correction of local meteo data is recommended. When local meteo data is used to control ventilation, the correction for local effects often is poor. This badly affects ventilation control. The obstacle corrections of the pressure simulation program may be utilised also to correct these data.

7. REFERENCES

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