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DESIGN OF THE INDOOR ENVIRONMENT A TEST OF APPLICATION OF pr ENV 1752 FOR THE CONSTRUCTION OF A SCHOOL

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SUMMARY AND CONCLUSIONS

The draft of the European prestandard 1752, entitled "Ventilation for buildings - Design criteria for the indoor environment" is intended to be a flexible tool for assisting the designer in providing a proper indoor environment for people in ventilated buildings. It specifies how the quality of the indoor environment, comprising the thermal environment, the air quality and the acoustic environment can be expressed.

In an informative annex to the standard, the "decipol" unit is proposed for the characterisation of perceived air quality, the emission of each pollution source being expressed by the "olf" unit.

The paper will describe one of the first (or the very first ?) test of application of the IAQ (indoor air quality) part of the standard to the design of a building, in this case the third European School in Brussels (2.500 pupils).

The paper comprises three parts :

1. description of the project of the 3rd European School in Brussels
2. summary of the content of the prestandard
3. application of the standard for the design of the school

Conclusions are :

1. Application of the standard in the case of low polluting buildings leads to realistic values of ventilation rates.

2. The "olf-decipol" method enables the designer to calculate either ventilation rate or comfort-category in different and specific situations.

3. Remaining problems are : the measurement of the sensory pollution load of building materials, the application at reasonable costs of the guidelines for design, construction and maintenance of HVAC systems, and the reliability of the "olf-decipol" method in the case of not low polluting buildings.

1. The 3rd European School in Brussels (fig. 1 and 2)

The school, comprising a kindergarten, a primary school and a secondary school (2.400 pupils in total), will be build in the years 1997 to 1999 on a 3.9 hectare plot situated on the campus of the ULB (French-speaking Free University of Brussels), along the Boulevard du Triomphe.

A tree-lined embankment separates it from the boulevard and constitutes a visual and sound barrier.

In designing the rough project, the Engineering Department of the Buildings Agency was particularly attentive to the quality of life of the occupants. The design gave priority to pedestrians by avoiding motorised traffic on the site (limited to technical and security vehicles).

The project is overall geared to a symmetrical axis running from north to south along the largest slope of the ground, which links Building A1 (administration and "restaurant") and Building M (culture pavilion).

The kindergarten A2 comprises 14 classrooms opening on one floor and in direct contact with the play grounds.

Four buildings are set out round the central space, on either side of the symmetry axis (C and D for the primary school, F and G for a part of the secondary school). The secondary school also occupies the semi-circular complex H, I, J. A field and omni-sport arena will also be built in this part of the site. A small building along those of the ULB (O) is made available for the students to relax. The pavilion situated at the centre of a green area (M) houses the cultural activities of secondary school students; it comprises an auditorium for 80 persons.

The out-to-out surface area is 31,000 m^2, and the cost of works is estimated at BEF 1,550 million.

2. The standard

pr ENV 1752 "Ventilation for buildings - Design criteria for the indoor environment" is a draft ("pr") European Prestandard ("ENV" instead of "EN"). The lifetime of an ENV is first limited to three years. After two years, members of CEN (European Committee for Standardisation) are requested to send in their comments, that will be transmitted to the Technical Board of CEN for further action. This paper is based on the "final draft" of July 1996.

The prestandard 1752 is intended to be a flexible tool for assisting the designer in providing a proper indoor environment for people in ventilated buildings. It deals with thermal environment, indoor air quality and acoustic environment. This paper deals only with the aspect "indoor air quality" (IAQ) for comfort[1].

The first way to determine design criteria for IAQ is to use a table where the required ventilation rate for design of different types of buildings and spaces are listed under certain assumptions. An abstract of this table, that applies for classrooms and auditoria is given here. (Table 1)

As we see, the prestandard offers three categories of environmental quality which may be selected in a space to be ventilated : categories A, B or C. These categories corresponds to different percentages of persons who find the environment unacceptable (= % dissatisfied).

As far as IAQ is concerned, categories A, B and C corresponds more or less to respectively 15, 20 and 30% dissatisfied (N.B. : the figures refer to people's initial judgement when entering a space).

Once the category is selected, the required ventilation rate can be calculated as the sum of :

1. a minimum ventilation rate to handle the pollution caused by the occupants only (no smokers)

2. an additional ventilation rate to handle the pollution caused by the building (including building materials, furnishing and HVAC equipment) ; there are two columns : one for low-polluting buildings and one for buildings that are not low-polluting ; in the third part of this paper we will discuss how to design a low-polluting building according to the prestandard

3. a further additional ventilation rate, if 20% of the occupants are smokers ; this column does not apply to classrooms nor auditoriums.

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[1] The prestandard also gives some indications about indoor quality for health purposes.

These ventilation rates are based on the occupancy listed in the table (0,5 person per m^2 floor for a classroom and 1,5 for an auditorium), and on the assumption that the ventilation effectiveness is one and that outdoor air of excellent quality is available.

An alternative way offered in an informative annex to the standard is to calculate the ventilation rate required for comfort by this equation (A6) :

$$Q_c = 10 . \frac{G_c}{C_{c,i} - C_{c,o}}$$

Q_c is the ventilation rate required for comfort, in litre per second

G_c is the sensory pollution load, in olf

$C_{c,i}$ is the desired perceived indoor air quality, in decipol

$C_{c,o}$ is the perceived outdoor air quality at air intake, in decipol

ϵ_v is the ventilation effectiveness

3. Application of the standard to the design of the school (classrooms and auditorium)

3.1. Classrooms

The "typical" classroom that we are describing here is designed for 25 pupils and has a floor area of 54 m^2. The mechanical ventilation system is described in figure 4. In winter, this system is only used to bring fresh air in the room, heating being provided by radiators. In summer, the supply air is at outdoor temperature.

According to the specifications, the finishing materials are as follows :

- floor : ceramic tile
- walls : brick + plastering + paint
- ceiling : panels, partly of painted plaster and partly of an acoustically absorbant material.

3.1.1. First way : use of table 1 of the prestandard

3.1.1.1.

First of all we have to control that the assumptions, on which the table is based, are actually fulfilled.

The room, with a floor area of 54 m^2, is designed for 25 pupils ; thus occupancy = 0,48 person per m^2 floor.

Comparing the ventilation system used in the classrooms (figure 4) with the examples in annex F of pr ENV 1752 (table F1), and knowing that the temperature difference between the supply air and the air in the breathing zone will be negative (summer) or slightly positive (winter) during occupation time, we can assume that ventilation effectiveness is 0.9 - 1.0.

We also can assume that outdoor air of excellent quality is available, since no motorised traffic is allowed on the site and no outdoor air intake are located near the boulevard (see figure 3).

3.1.1.2.

The second step is to determine if the building (the room) is designed as a low-polluting one or not. According to annex G of the standard, the building has to fulfil two conditions to be "low polluting".

1st condition

Materials in a space may belong to the following three categories, depending on the emission of pollutants.

Category M1

Category M1 is designated for emission-tested materials whose emissions fulfil the following requirements :

- *emission of total volatile organic compounds (TVOC) is below 0,2 mg/m^2h*
- *emission of formaldehyde (H_2CO) is below 0,05mg/m^2h*
- *emission of ammonia (NH_3) is below 0,03 mg/m^2h*
- *emission of carcinogenic compounds according to category 1 of IARC classification*[2] *is below 0,0005 mg/m^2h*

Category M1 includes also natural materials that are known to be safe in respect of emissions :

- *brick*
- *natural stone and marble*
- *ceramic tile*
- *glass*
- *metal surface*

Category M2

Category M2 is designed for emission-tested materials whose emissions fulfil the following requirements :

- *emission of total volatile organic compounds (TVOC) is below 0,4 mg/m^2h*
- *emission of formaldehyde (H_2CO) is below 0,125mg/m^2h*
- *emission of ammonia (NH_3) is below 0,06 mg/m^2h*
- *emission of carcinogenic compounds according to category 1 of IARC classification is below 0,005 mg/m^2h*

Category M3

Category M3 includes materials that do not have emission data or the emissions exceed the values specified for materials in Category M2.

For a low-polluting building, dominating surface materials should be from Category M1 ; less than 20% of the area should be from Category M2 and no significant area should be from Category M3.

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[2] *World Health Organisation (1987) Air quality guidelines for Europe.* Copenhagen, WHO Regional Office for Europe, p. 22.

In the case of the finishing materials listed above, only paints are concerned. Conformity with the specifications of annex G will be checked when the contractor will propose the painting products to be used for the walls and the ceilings of the classrooms.

2nd condition

The guidelines on the design of HVAC systems in low polluting buildings given in FISIAQ-classification are to be fulfilled.

In fact, the European School is built in accordance to Belgian codes and standards. As far as HVAC systems are concerned, the general specifications are given in a document (guide) called "Cahier des charges-type n° 105" edited by the Buildings' Agency.

A comparison was made between this document and the FISIAQ specifications. It appeared that the following important items are included in both guidelines :

- tightness of the ducts and accessories

- the supply air of the air handling units shall be cleaned with filters whose dust removal efficiency fulfils at least the European class EU7 ;
  the air shall not bypass the filter media through the holes or leakage's between the frames and air handling units ; the air handling unit shall be airtight so that air does not flow through leakage's to the supply air between fan and filter due to under pressure in the system

- the operation and maintenance instructions of air-handling equipment shall be handed over to the building users during the commissioning process of the air-conditioning system

- fibre filters of air-handling units shall be replaced according to final pressure drop defined by the designer

3.1.1.3.

Using table 1 for low polluting buildings, we find that required ventilation rate is equal to

- 5,0 + 1,0 = 6,0 $l/(s.m^2)$ if category A is selected
- 3,5 + 0,7 = 4,2 $l/(s.m^2)$ if category B is selected
- 2,0 + 0,4 = 2,4 $l/(s.m^2)$ if category C is selected

For the classrooms of the European School, category C was selected to reduce costs, and taking into account that opening of windows for natural ventilation at higher rates is possible during a large part of occupation time, if necessary.

Thus, the ventilation rate in a classroom is equal to 2,4 x 54 = 130 l/s.

3.1.2. Second way : use of equation A6 of the prestandard

To use this equation, we need to know

- the desired perceived indoor air quality, in decipol
- the perceived outdoor air quality at air intake, in decipol
- the sensory pollution load, in olf

For category C, the perceived air quality of the indoor air will be equal to 2.5 dp, according to table 5 of the standard.

In towns, when good air quality is available, the perceived air quality of the outdoor air is better than 0,1 dp, according to table A9 of the standard.

Last but not least, we have to estimate the expected sensory pollution load caused by occupants, finishing materials and HVAC system.

- For the occupants, we can use the values given in table A6 of the standard, i.e. 1.2 olf for a child in the kindergarten, 1.3 olf for a child in the primary and secondary school, and 1 olf for the teacher.

- For the building, including ventilation system, table A8 of the standard gives target-values for new buildings, either low polluting (0,1 olf per m² floor) or not (0,2 olf per m² floor). The European School is designed as a low polluting building, so we take the value of 0,1 olf per m² floor, i.e. 5,4 olf for the classroom.

  As for the first way (use of table 1), conformity with the target value has to be checked when the contractor propose the finishing materials, according to the specifications.

  (N.B. : we assume that the ventilation system itself, being designed more or less in accordance with FISIAQ-guidelines, does not pollute at all).

  This will be the big difficulty of the use of equation A6, since checking of the sensory pollution load of finishing materials needs a widely accepted test method, with acceptable reliability and cost.

  To know if such a test method was available, a letter was sent out in August 1995 to all (14) laboratories involved in the project "European database on indoor air pollution sources in buildings" asking them if they could carry out such measurements, the degree of precision that could be expected and the involved costs. It appeared from the answers, that a document defining a

method to measure the sensory pollution emission in "olf" in a sufficiently precise and complete way didn't yet exist at that time.
In the meantime, a document entitled "Protocol for sensory assessments" was prepared in the frame of the Data Base project which is planned to be finished during 1997. A letter, similar to that of August 1995, will be sent to the laboratories in April 1997.[3]

Nevertheless, if we now apply equation A6, using the selected values for the perceived indoor and outdoor air quality and for the sensory pollution load caused by the occupants and the building, we can calculate the required ventilation rate.

- sensory pollution load occupants = (1.3 x 25) + 1 = 33.5 olf
- sensory pollution load building = (0.1 x 54 = 5.4 olf
- total sensory pollution load = 38.9 olf
- perceived indoor air quality = 2.5 dp
- perceived outdoor air quality = 0.1 dp
- ventilation effectiveness = 0.9 (see 3.1.1.1.)
- ventilation rate required for comfort =

$$10\,\frac{38.9}{2.5-0.1}\,\frac{1}{0.9} = 180\ l/s$$

In this case, the use of equation A6 gives a higher ventilation rate than table 1, since equation A6 takes into account a sensory pollution load of 1.3 olf per child and a ventilation effectiveness of 0.90. It is the advantage of this method to enable the designer to calculate the ventilation rate in accordance to the actual conditions in each particular situation.

3.2. Auditorium

The auditorium is located in pavilion M that houses the cultural activities of secondary school students.
This room is designed for an occupancy of 80 persons (attendance and "actors" - musicians a.s.o.) and has a floor area of 102 m². The airconditioning system is described in figure 5. The finishing materials are the following :

- floor : glued synthetic carpet
- walls : concrete blocks + plastering + paint
- ceiling : painted plaster panels

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[3] If the answers provide new elements, these will be included in the poster and discussed during the technical session.

- acoustical plexiglass shells on the podium
- seats : not easily flammable foam + woven material

3.2.1. First way : use of table 1 of the prestandard

3.2.1.1. Assumptions

- occupancy : 0,78 person per m^2 floor ; this is about half of the value mentioned in the table
- ventilation effectiveness = 1 (in accordance to the second case of table F1 of the standard)
- outdoor air of excellent quality is available.

3.2.1.2.

The auditorium is designed as a low-polluting space.
A very important step will be the control of the conformity with the specifications of annex G of the standard (quantity of materials belonging to categories M1, M2 and M3), especially carpets, seats and paintings.

3.2.1.3.

Using table 1 for low polluting buildings, we find that the required ventilation rate in the auditorium is equal to

- in category A : 16 $l/(s.m^2)$, i.e. 1.632 l/s
- in category B : 11,2 $l/(s.m^2)$, i.e. 1.142 l/s
- in category C : 6,4 $l/(s.m^2)$, i.e. 653 l/s

The auditorium was designed in accordance to category C, taking into account that the actual occupancy will be much lower than the value on which table 1 is based. As a result of this, the actual comfort in the room will be higher than category C.

3.2.2. Second way : use of equation A6 of the prestandard

- perceived indoor air quality, category C (table A5 of the standard) : 2.5 dp
- perceived outdoor air quality : 0.1 dp
- sensory pollution load caused by the occupants :
  80 occupants x 1 olf/person = 80 olf
- sensory pollution load caused by the building :
  102 m^2 x 0.1 olf/m^2 = 10.2 olf
- total sensory pollution load = 90.2 olf
- ventilation effectiveness = 1

If we assume that a method for testing the pollution load of materials will be soon available, so it will be possible to check the value of 0.1 olf/m², we can calculate the required ventilation rate for comfort in the auditorium, using equation A6 :

$$Q_c = 10.\frac{90.2}{2.5 - 0.1} = 375 l/s$$

Using the same equation, we can calculate the comfort-category that actually will be reached in the auditorium with a ventilation rate of 653 l/s.

$$C_{c,i} - C_{c,0} = 10.\frac{90.2}{653} = 1.4\ dp$$

$$C_{c,i} = 1.5dp$$

This is about category <u>B</u>. (see table A5 of the standard)

This case again illustrates the ability of the method using equation A6 to calculate either the ventilation rate to obtain a given comfort-category, or the comfort-category with a given ventilation rate, and this in different and specific situations.

TABLES FROM THE DRAFT-PRESTANDARD pr ENV 1752

Table 1

Design criteria for spaces in different types of buildings.
This table applies for the occupancy listed in the table and for a ventilation effectiveness of one.

Type of building/ space	Activity	Occupancy	Category	Operative temperature °C		Maximum mean air velocity m/s		Sound pressure	Minimum ventilation rate, i.e. for occupants only	Additional ventilation for building (add only one)		Additional ventilation when smoking is allowed l/s (m² floor)
	met	person/ (m² floor)		Summer	Winter	Summer	Winter	dB(A)	l/s m²	Low-polluting building l/s m²	not low-polluting building l/s m²	
Classroom	1,2	0,5	A	24,5±0,5	22,0±1,0	0,18	0,15	30	5,0	1,0	2,0	-
			B	24,5±1,5	22,0±2,0	0,22	0,18	35	3,5	0,7	1,4	-
			C	24,5±2,5	22,0±3,0	0,25	0,21	40	2,0	0,4	0,4	-
Auditorium	1,2	1,5	A	24,5±1,0	22,0±1,0	0,18	0,15	30	15[1]	1,0	2,0	-
			B	24,5±1,5	22,0±2,0	0,22	0,18	33	10,5	0,7	1,4	-
			C	24,5±2,5	22,0±3,5	0,25	0,21	35	6,0	0,4	0,8	-

[1] It may be difficult to meet the Category A draught criteria.

Table F.1
Examples of ventilation effectiveness in the breathing zone of spaces ventilated in different ways

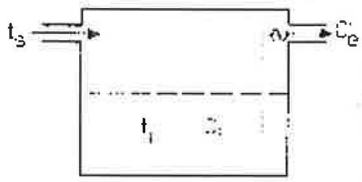
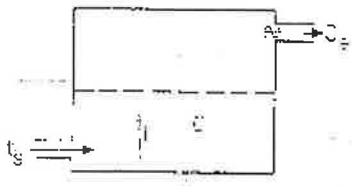
Mixing ventilation		Mixing ventilation		Displacement ventilation	
					
Temperature difference between supply air and air in breathing zone t_s - ti °C	Ventilation effectiveness	Temperature Difference between supply air and air in breathing zone t_s - ti °C	Ventilation effectiveness	Temperature difference between supply air and air in breathing zone t_s - ti °C	Ventilation effectiveness
< 0	0.9 - 1.0	< -5	0.9	> 0	1.2 - 1.4
0 - 2	0.9	-5 - 0	0.9 - 1.0	0 - 2	0.7 - 0.9
2 - 5	0.8	> 0	1.0	> 2	0.8 - 0.7
> 5	0.4 - 0.7				

Table A5
Three categories of perceived indoor air quality

Category	Perceived air quality		Required Ventilation rate [1)] l/s olf
	% dissatisfied	dp	
A B C	15 20 30	1,0 1,4 2,5	10 7 4

[1)] The ventilation rates given are examples referring exclusively to perceived air quality. They apply only to clean outdoor air and a ventilation effectiveness of one.

Table A9
Examples of outdoor levels of air quality

	Perceived air quality dp	Air pollutants				
		Carbon dioxide mg/m³	Carbon monoxide mg/m³	Nitrogen dioxide µg/m³	Sulfur dioxide µg/m³	Particu-lates µg/m³
Excellent	0	680	0-0,2	2	1	< 30
In towns, good air quality	< 0,1	700	1-2	5-20	5-20	40-70
In towns, poor air quality	> 0,5	700-800	4-6	50-80	50-100	> 100

NOTE : There is no direct relation between perceived air quality and the pollutants listed in this table. The values for the perceived air quality are typical daily average values. The values for the four air pollutants are annual average concentrations.

Fig. 1
3rd European School in Brussels - General plan

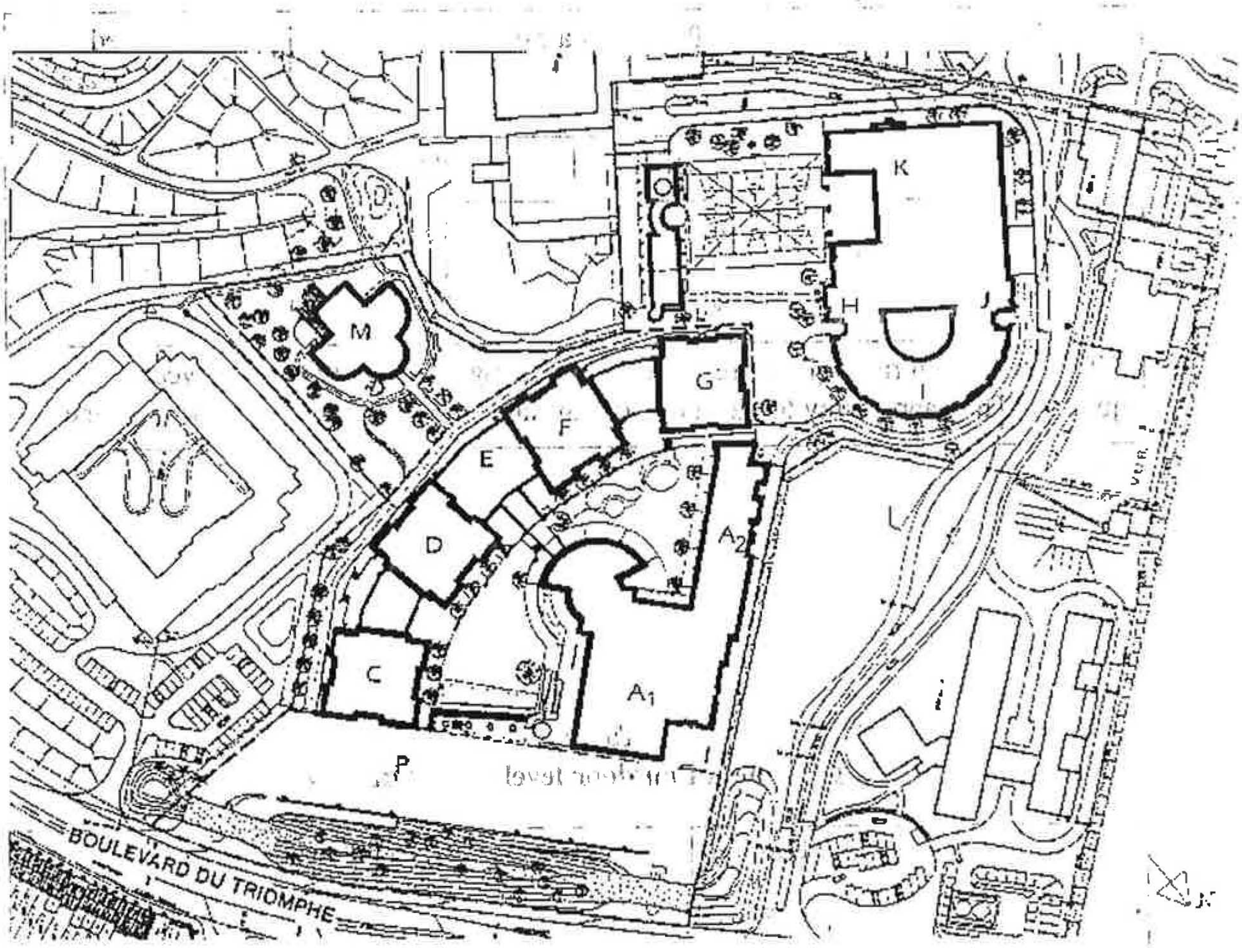
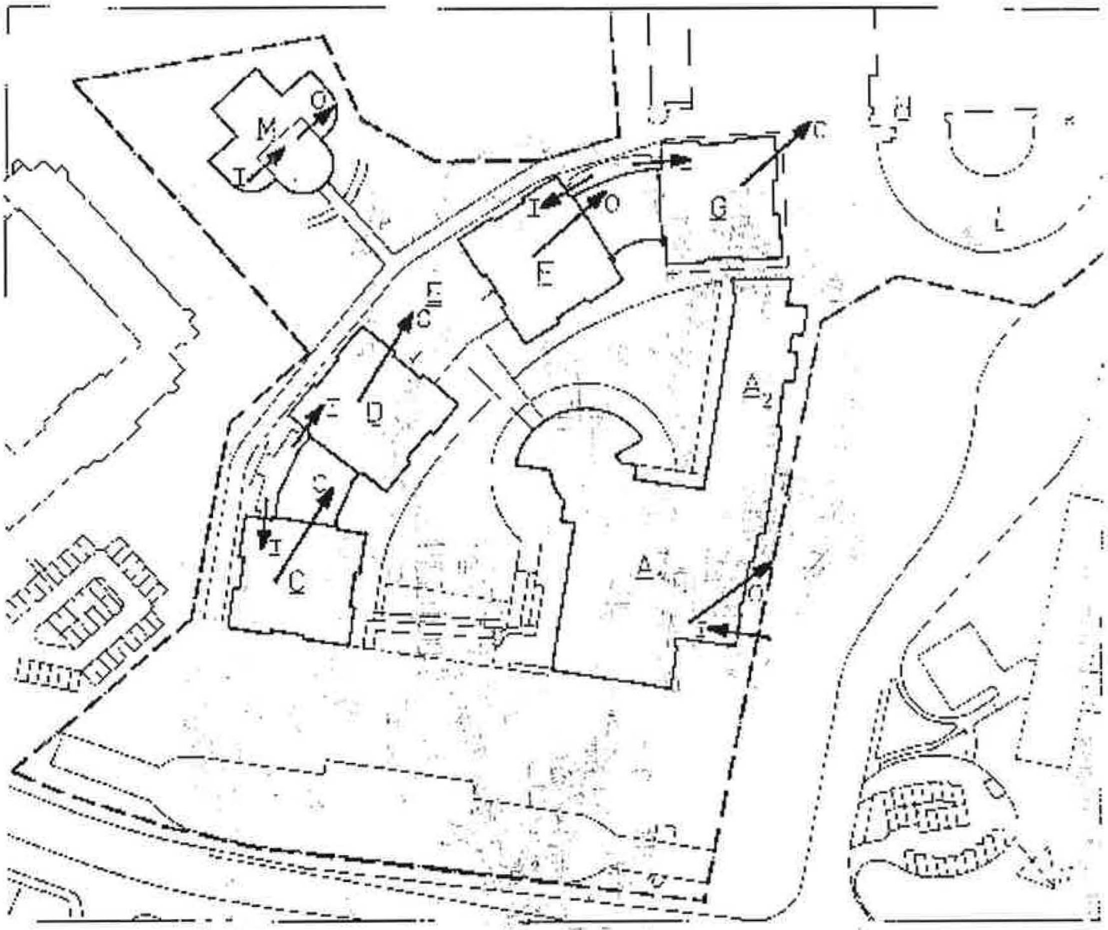


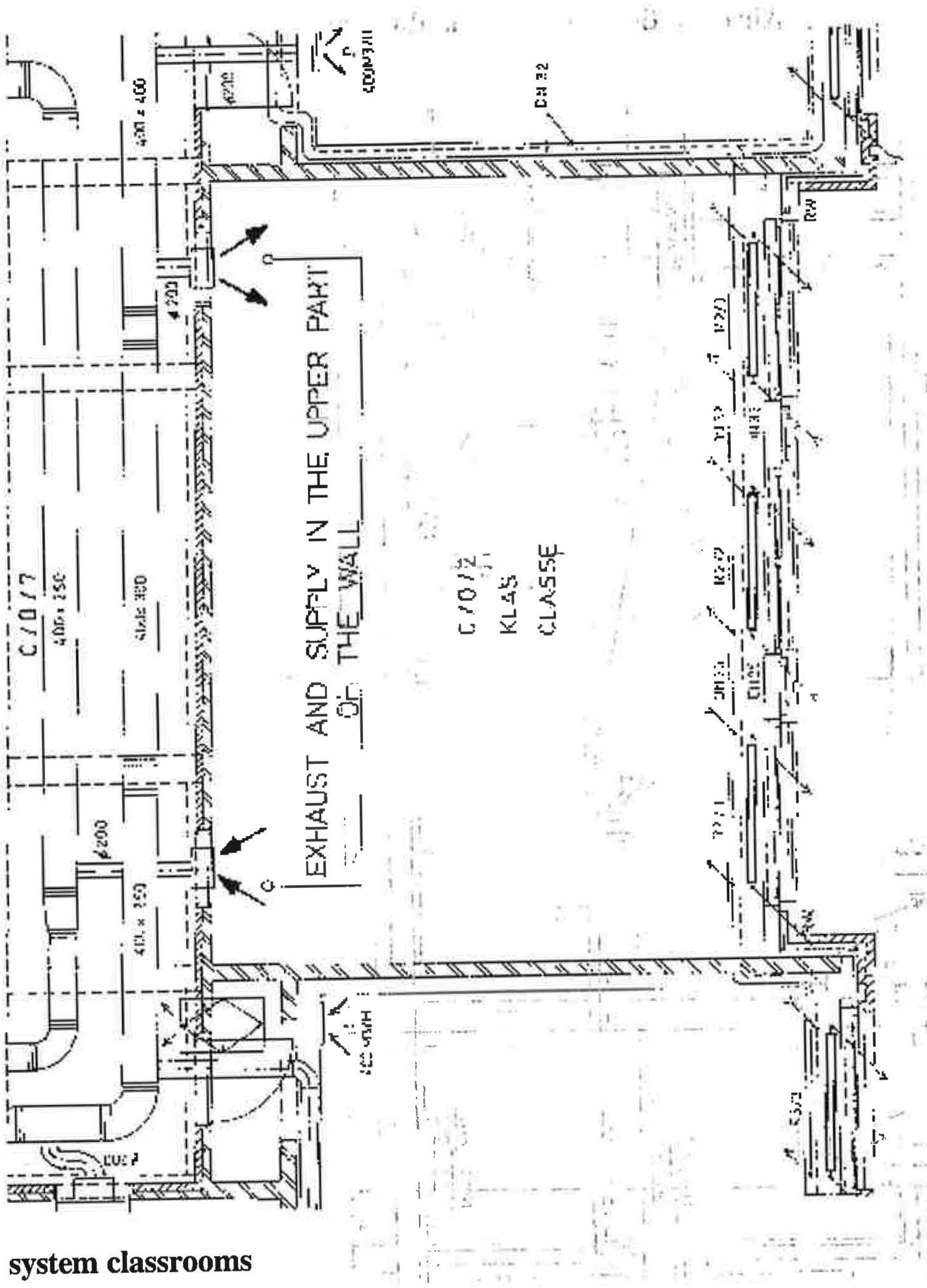
Fig. 2
3rd European School in Brussels - South-North axis

Fig. 3
Air intakes



I = AIR INTAKE
O = AIR OUTLET (ROOF)

Fig. 4



Ventilation system classrooms

Fig. 5
Air conditioning system auditorium