Simplified Analysis of Naturally Ventilated Desert Buildings

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The verification of a simplified thermal analysis procedure and its application to naturally ventilated desert buildings are discussed. Measurements for buildings in the Negev Desert, done independently by the Desert Architecture Unit of the Jacob Blaustein Institute for Desert Research, were inter alia used to verify the simplified thermal analysis procedure QUICK, developed by the Centre for Experimental and Numerical Thermoflow. As detailed information for validation purposes is not always readily available to researchers, the measurements as well as the buildings' descriptions are given in detail in this paper.

The effect of natural ventilation strategies on the indoor air temperatures is also investigated for the desert buildings. A simplified but novel procedure to calculate the air change rates through the building from the measured wind speeds, building geometry and surroundings is proposed. Hourly air change rates determined with the proposed procedure are employed in the simulations with QUICK. The simulations and measurements showed that sensible ventilation strategies for certain buildings may reduce the maximum indoor temperature by as much as 2°C. It is now possible to establish such strategies at the early design stage.

1. INTRODUCTION

THE FOUNDATION for a good thermal design is laid during the sketch design phase. During this phase a user-friendly computer program is needed, which is able to answer the important questions a designer has [1]. These questions are mostly about comparisons of different design alternatives. For example, what is the effect of window operation on the indoor air temperatures? A simplified thermal analysis procedure which can answer such questions was therefore developed and implemented in a computer program QUICK [2].

One of the most important steps in the development of a thermal analysis computer program is verification against measurements. Verification is often neglected due to a lack of funds and time as well as insufficient information in publications. Although more than fifty validation studies were successfully done in different types of South African buildings, it was decided to verify independently the procedure for other types of buildings in the Negev Desert in the Northern Hemisphere. Independent verification is very important because it ensures unbiased evaluation. All the information and data are also given in a format useful for verification purposes by any researcher.

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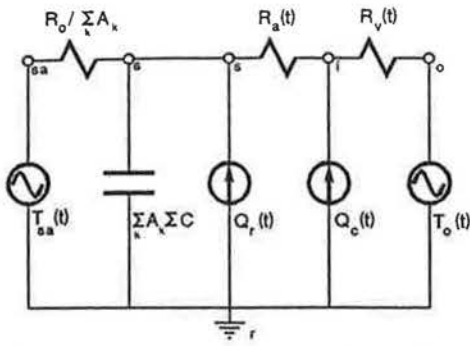† Desert Architecture Unit, Jacob Blaustein Institute for Desert Research, Sede-Boker Campus, Israel.

For the buildings in the Negev Desert a new treatment of time varying natural ventilation flow rates was needed. As opposed to most other simple ventilation prediction models, the proposed simplified procedure does not only take into account the effect of the wind speed but also the volume of the zone as well as the position and characteristics of the openings in the building envelope and in internal walls. It also accounts for wind direction and shading from adjacent buildings. Different ventilation strategies in the desert climate for the specific buildings were investigated with the new method.

2. THERMAL SIMULATION

2.1. *Background*

The original method was developed by Mathews [3] for completely passive buildings. A thorough theoretical discussion on new extensions is given in a recent publication [2]. Consequently only the salient features will be highlighted in this paper.

With the proposed method it is endeavoured to simulate all the important heat flow phenomena in a building zone by means of the simplified thermal network given in Fig. 1. the following thermal properties can be identified in the network:

—The time dependent forcing inputs are the radiative heat source ($Q_r(t)$) acting on the internal structure, the sol-air temperature ($T_{sa}(t)$) acting on the exterior structure, the convective heat source ($Q_c(t)$) and the

Fig. 1. Simplified thermal network representing a building zone.

outdoor air temperature $(T_o(t))$ both acting on the internal air volume.

—There are three time dependent resistances in the network, namely the weighted shell resistance $(R_o(t))$, the indoor air resistance $(R_a(t))$ and the ventilation resistance $(R_v(t))$.

—The capacitor (ΣC) in the network is a novel feature of the method. It represents the active thermal capacity of the building zone, taking into account the relative position and thermal properties of mass and insulation as well as the fact that a temperature differential exists across the building element [4].

The indoor air temperature $(T_i(t))$ is obtained by means of a novel periodic procedure carried out in the time domain [5]. The thermal resistances in the network are time-dependent due to, *inter alia*, changing wind velocities, window operation and forced mechanical ventilation. Usually time-dependent thermal parameters lead to time consuming iterative solution techniques [6, 7]. However, the solution technique developed for this model facilitates a fast and accurate simulation of time-dependent thermal parameters [5].

Another important feature of the thermal model is the fact that the active thermal capacity of a building zone (ΣC) accounts for the effect of multi-layered floors in contact with the ground [4]. Various other simplified and even comprehensive methods do not model this aspect efficiently [2].

In order to simulate all the complex heat flow phenomena in a building zone, the procedure had to be simplified with certain assumptions which are discussed in [2]. A summary of the major assumptions is given below.

—A single zone approach is followed. Heat exchange between different interior zones is thus not simulated.

—Due to the lumping of interior elements, a single structure temperature at the structure node (s) results.

—Radiation on the interior surfaces of all the building elements is assumed to be evenly distributed and is thus simulated with a single term $Q_r(t)$.

—The room air temperature is uniform over the whole volume.

—A combined indoor convective and radiative heat transfer coefficient is used.

—A single value for the active heat capacity of a zone (ΣC) is used.

—The heat capacity of the indoor air volume is negligible.

2.2. Ventilation

An important contributor to errors in the thermal analysis of naturally ventilated buildings is inaccurate air flow predictions. These predictions are important for designers in countries such as Israel and South Africa where most buildings are naturally ventilated. Prediction models for natural ventilation range from simplified to comprehensive ones. Comprehensive procedures are usually of limited use to designers as they are laborious to implement and the required input data are difficult to obtain. On the other hand, the most commonly used simplified procedure is based on the following suspect correlation equation, derived from measurements in buildings with diverse geometries and window placement:

$$ach = a + b \cdot V \tag{1}$$

where *ach* is the air change rate per hour, V the wind speed at a reference height and a and b are empirically determined coefficients. Measurements however showed that an unsatisfactory correlation exists between air change rates and wind speeds when using the above-mentioned equation. Errors resulting from this approach were discussed [2] and it was shown that the following equation, as a first approximation, should provide a better solution for inclusion in a thermal model:

$$ach \cdot \frac{Vol}{A} = a_{new} + b_{new} \cdot V. \tag{2}$$

This equation retains some of the more important characteristics of a building, such as the internal volume (Vol) as well as the total open areas (A).

Measurements of natural ventilation flow rates were done for full scale and model buildings. These are given in Figs 2 and 3 respectively using the approaches suggested by equations (1) and (2). A curve (equation (2)) was fitted to the data in Fig. 3 which represents a good fit with a regression coefficient of 0.95. On the other hand, it would be senseless to try and fit a single curve (equation (1)) to the data in Fig. 2. It is clear that the proposed equation (2) is an improvement on the popular equation
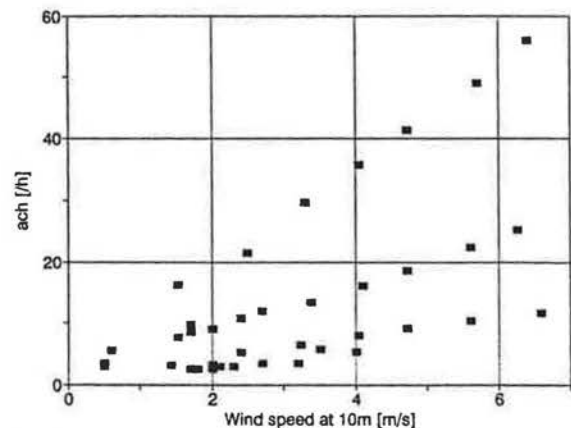

Fig. 2. Measured natural ventilation flow rates (*ach*) versus the wind speed (V) measured at a reference height of 10 m.
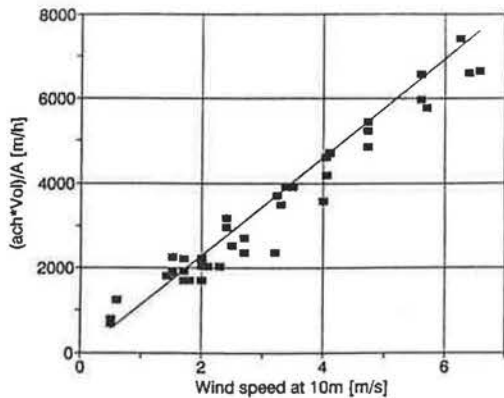
Fig. 3. Measured values of $(ach*Vol)/A$ versus the wind speed (V) measured at a reference height of 10 m.

Fig. 4. Definition of wind direction β used in equation (4).

(1) previously employed in the simulations [2]. The proposed equation (2) was thus further developed by the Centre for Experimental and Numerical Thermoflow for the purpose of this paper.

The new equation attempts to account for building geometry, wind shading and direction, internal flow resistance, temperature effects as well as window type and position. The proposed equation is represented in the form of a non-dimensional ventilation parameter as follows:

$$\frac{ach \cdot Vol}{C_d A \cdot V_h} = f(\phi_1, \phi_2, \ldots, \phi_n) \qquad (3)$$

with $C_d A$ defined as the representative permeability of the building, V_h the free stream wind velocity at roof height and f a function of any number of relevant parameters $\phi_1, \phi_2, \ldots, \phi_n$. These parameters can *inter alia* include the orientation of the building with respect to the wind direction, the effect of shading from adjacent buildings, the number of openings on the building envelope, the temperature difference between the indoor and outdoor air and various geometrical characteristics of the building.

The detail of equation (3) applicable to a building with two windows open to the outside and situated on directly opposite walls of the building, as is the case for the desert buildings in the present study, has already been derived. The derivation of the equation is based on measurements of natural ventilation flow rates for full scale and model buildings. The equation for the non-dimensional ventilation parameter is:

$$\frac{ach \cdot Vol}{C_d A \cdot V_h} = 3500 \tanh (2.8(abs(\sin \beta))^{0.85})$$

$$\cdot \tanh \left(0.1 \left(\frac{x}{h} \right)^{0.8} \right) \qquad (4)$$

where β is the wind direction as defined in Fig. 4 and x/h is a wind shading factor with x the fetch length to the closest building of comparable height on the windward side and h the roof height of the building. The windspeed (V_h) is known from weather data, while the volume (Vol) of the zone can be calculated from the building plans.

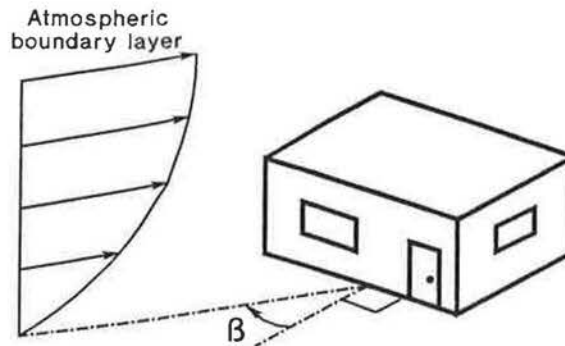The permeability coefficient $C_d A$ for the building is

calculated as

$$C_d A = \frac{\prod_{i=1}^{n} (C_{d_i} A_i)}{\sqrt{\sum_{j=1}^{n} \left[\prod_{\substack{i=1 \\ i \neq j}}^{n} (C_{d_i} A_i)^2 \right]}} \qquad (5)$$

where n is the number of openings in series through which the air flows and C_{d_i} and A_i are the discharge coefficient and area respectively of opening i. Any number of internal walls with openings is allowed.

Equation (4) was used to predict the air flow rates for the desert buildings investigated in this paper. It should be noted that time varying ventilation rates were used for the present analysis of the buildings in the desert, while for previous simulations it was assumed that the rates were constant for the entire analysis period.

3. MEASUREMENTS

3.1. *Background*

For a good thermal design tool, input data should be kept to the essential. It should also be readily available to the building designer. Climatic data for a design day for all the important centres in Southern Africa are readily available, which is not true for other periods. For sketch design purposes, a very good idea of the thermal performance of a building can be achieved by using typical cold and hot design days. It was therefore decided to use a 24-hour period for design analyses, although any period of time can be simulated by the method.

To conform to the design procedure, an averaged 24-hour period, calculated from the available experimental data was thus used for validation purposes. This 24-hour period can be seen as a design day representation of the actual measurements. For validation purposes an average day was calculated over a period of five to seven consecutive days. In the case of large variations in the outdoor environment due to periods when rain occurred, the average day was calculated from a selection of consecutive dry days.

Before the measurements were done in the Negev Desert more than 50 verification studies had been performed in buildings in South Africa. These buildings included office blocks, shops, schools, residential buildings, townhouses, experimental buildings, factories and agricultural buildings. These validation studies showed
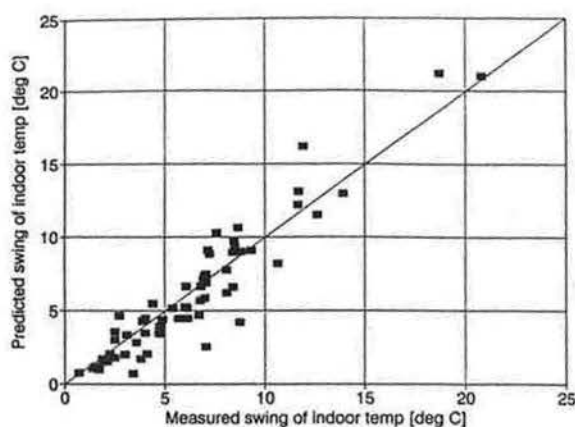
Fig. 5. Comparison between measured and predicted indoor air
temperature swings for over 50 case studies.

that the thermal model discussed earlier could simulate
the most important thermal properties in passive build-
ings. A summary of these studies is presented in Figs 5
and 6. Figure 5 shows a comparison between predicted
and measured indoor air temperature swings, defined as
the difference between the maximum and minimum air
temperatures. From the large variation in swings, 0.7
to over 30°C, it is clear that the buildings used in the
simulations differed significantly in active thermal mass.
Figure 6 shows a comparison between predicted and
measured indoor air temperature means. Both com-
parisons are acceptable for design purposes.

No measurements were done for infiltration and natu-
ral ventilation flow rates during the validation studies. In
the previous validation studies for the South African
buildings equation (1) was used to calculate air change
rates from wind speed data. In the present case of the
desert buildings equation (4) was used.

3.2. *Description of desert buildings*

The buildings in the Negev Desert are discussed in
detail in this paper. We believe that it contributes to this
field, as new thermal models must always be compared
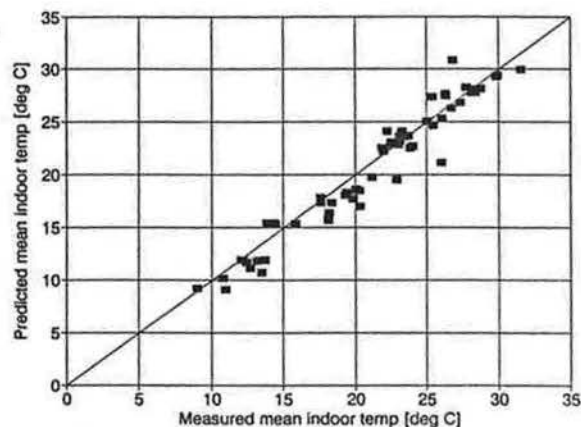to measured data to verify assumptions. Although a very

Fig. 6. Comparison between measured and predicted indoor air
temperature means for over 50 case studies.

important aspect, detailed measurements are usually
difficult to obtain [8]. The building and environmental
data are therefore given here in a form that will facilitate
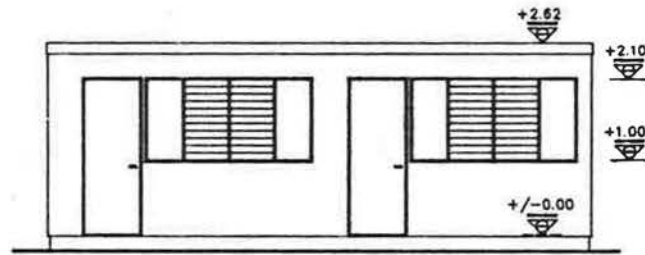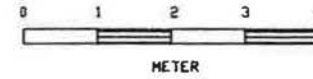validation studies carried out by other researchers.

Two types of buildings were chosen for the validation
of the simulated results—a low mass transportable pre-
fabricated unit, Fig. 7, and a fairly massive, precast con-
crete dormitory building, Fig. 8. The buildings are situ-
ated in the Negev Desert in Israel at longitude 34°50′ East
and latitude 30°50′ North. The standard time longitude
is 30° East.

The low mass prefabricated unit, situated free-standing
in a fairly open space, was approximately 7.3 by 3.7 m
and about 2.6 m high (Fig. 7). It was placed on steel
beams so that it was about 20 cm above the ground. The
external walls were made of panels, consisting of 5 cm
thick polystyrene insulation sandwiched between 1 cm
thick gypsum boards, in a light steel stud frame. The
floor and roof were insulated in a similar manner, diff-
ering only in the finishing details. The floor had laminated
PVC on 2 cm plywood sheet and the roof 8 mm particle
board with an external fibreglass skin. The north and
south facing walls had single glazed windows with alu-
minium frames. The windows were fitted with external
shading devices consisting of openable PVC louvres,
aligned horizontally. The building was off-white in
colour. An interior partition divided this unit into two
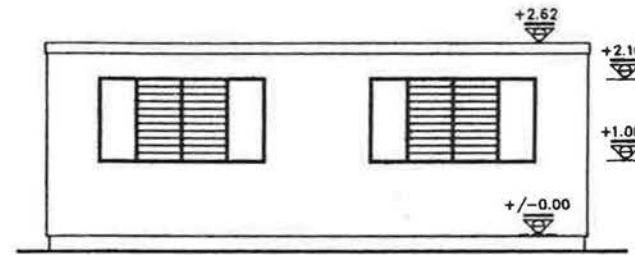rooms, with only the eastern room monitored.

The precast concrete unit monitored was an end unit
in an arrangement consisting of twenty rooms laid out in
two parallel rows running east-west (Fig. 8). The unit
consisted of a precast concrete box approximately 3.5 by
7.6 m and about 2.6 m high. The concrete floor had 13
cm of polystyrene insulation between structural ribs 55
cm long. The roof consisted of a 9 cm concrete slab with
4 cm of exterior polystyrene insulation. The walls were a
"sandwich" of 6 cm thick polystyrene insulation between
6 cm thick concrete panels, with external off-white
plaster. Each unit also had a sloping roof of corrugated
asbestos sheet painted red. The air space formed between
the exterior shell and the flat concrete ceiling was poorly
ventilated. Each unit has single glazed windows in alu-
minium frames incorporated in one end-wall. The win-
dows were fitted with external openable PVC louvres as
a shading device. The opposite wall had a wooden door
and two small glass-louvre windows which were not
shaded.

Temperatures were recorded on Richard–Pekly ther-
mographs with an accuracy of 0.5°C. Global radiation
was measured on an Eppley PSP pyronometer and direct
beam radiation on an Eppley Nit pyronometer. A Lam-
brecht transmitter recorded wind speeds at a height of 1
metre above ground level. Wind speed recordings were
made every 3 minutes and an average for each hour was
calculated. The environmental data and indoor tem-
peratures are given in Tables 1, 2 and 3. Measurements
were done for 3 periods of seven days each. For reasons
discussed earlier these measurements were averaged to
obtain 3 design days of 24 hours each. The indoor tem-
peratures given in the tables are for the two building
zones which were analyzed. Table 1 gives the relevant
data for the first period analyzed. During this period the
windows were opened during the night from 20.00 h to

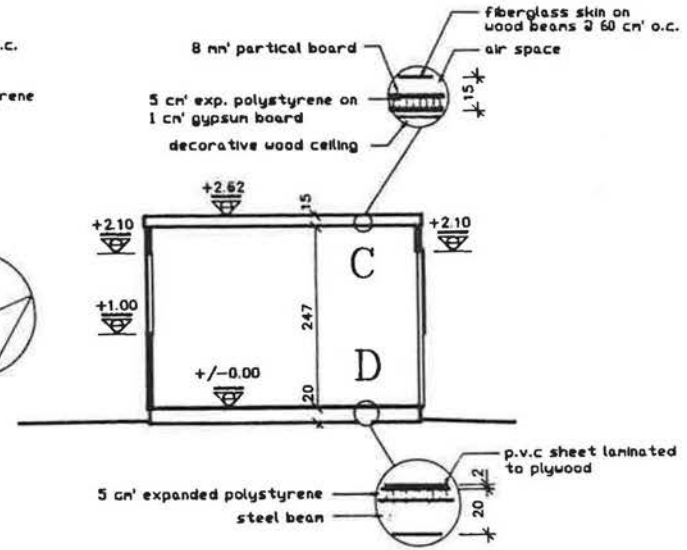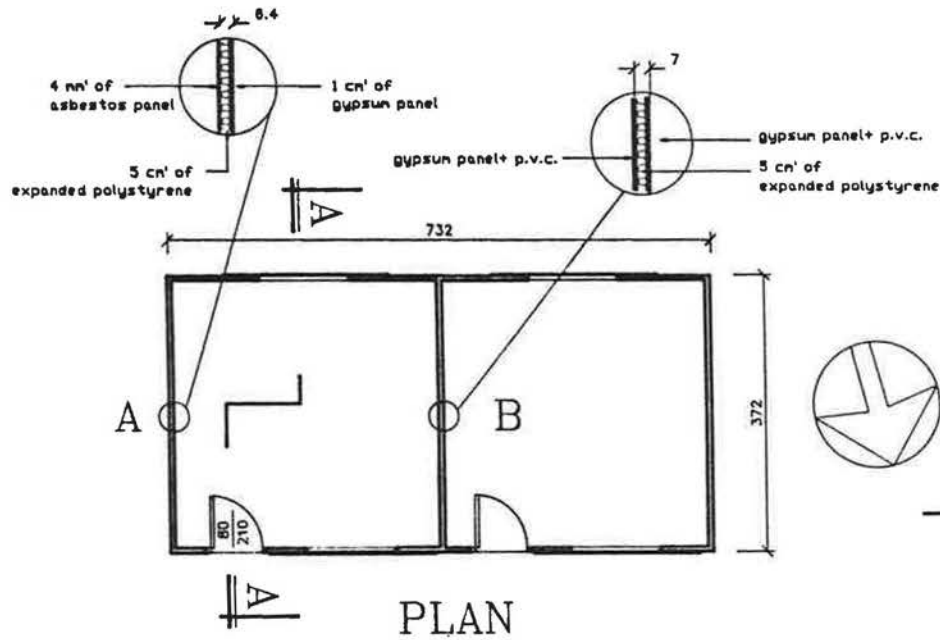# LIGHT-WEIGHT PREFABRICATED BUILDING

METER

NORTH ELEVATION

+2.62
+2.10
+1.00
+/-0.00

SOUTH ELEVATION

+2.62
+2.10
+1.00
+/-0.00

8.4

4 mn' of asbestos panel

1 cn' of gypsun panel

5 cn' of expanded polystyrene

7

gypsun panel+ p.v.c.

gypsun panel+ p.v.c.

5 cn' of expanded polystyrene

732

372

A

B

PLAN

80
210

fiberglass skin on wood beans @ 60 cn' o.c.

8 mn' partical board

air space

5 cn' exp. polystyrene on 1 cn' gypsun board

decorative wood ceiling

+2.62
.15
+2.10

C

+1.00

247

D

+/-0.00

20

p.v.c sheet laminated to plywood
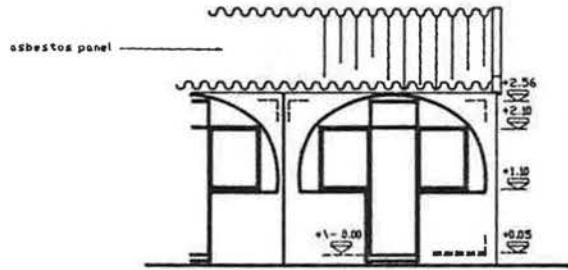
5 cn' expanded polystyrene
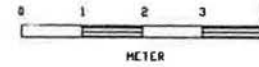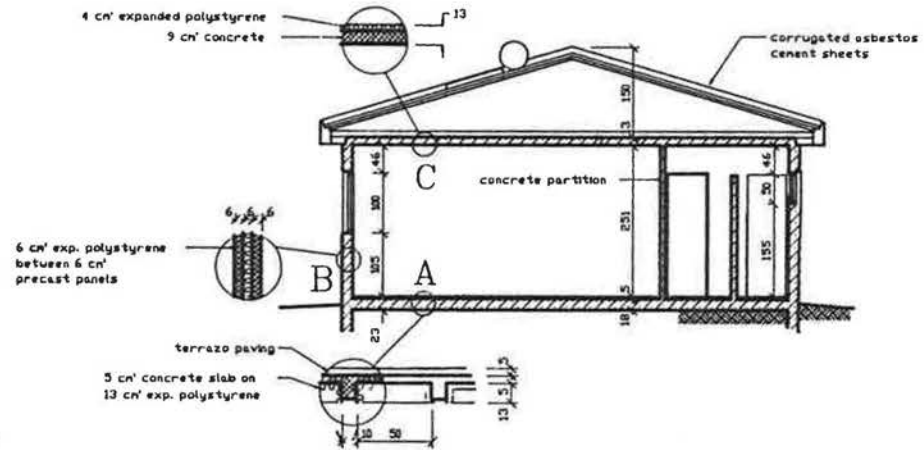
steel bean

20

SECTION A-A
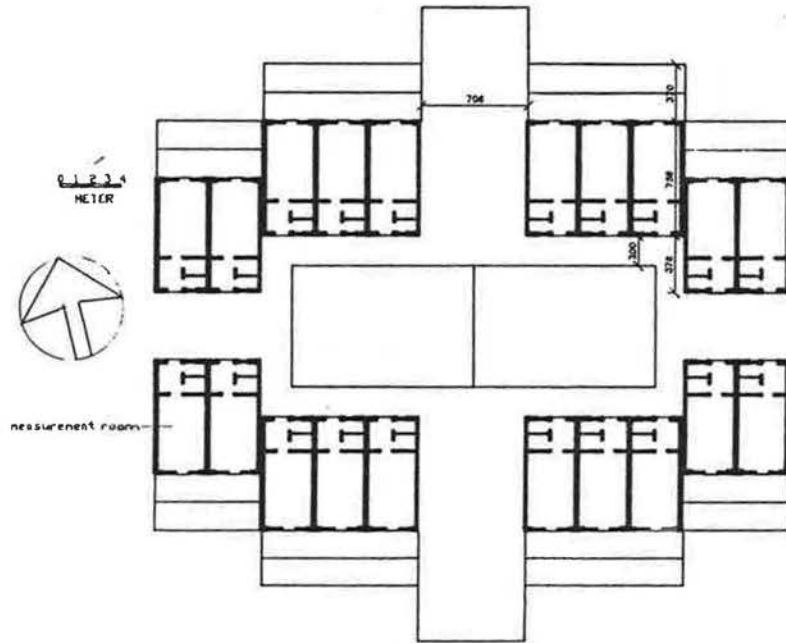
Fig. 7. Plans of low mass prefabricated unit.

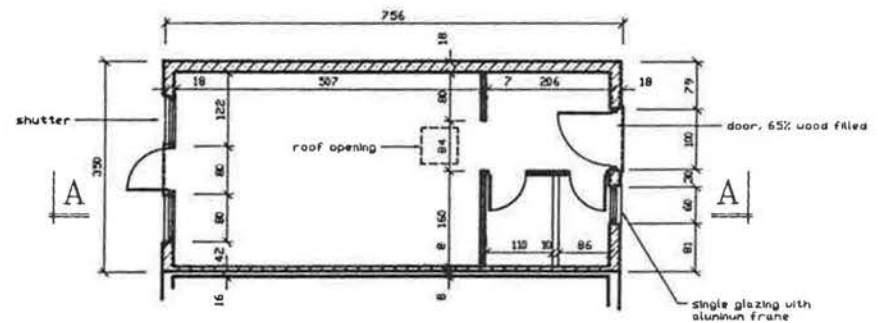# PRECAST CONCRETE DORMITORY UNITS

Fig. 8. Plans of precast concrete unit.

Table 1. Measured verification data for the period 11/07/88 to 18/07/88. Windows were closed 24 hours of the day

	Environmental data				Indoor temps	
Hour	Outdoor temp °C	Global radiation kW m^{-2}	Diffuse radiation kW m^{-2}	Wind speed m s^{-1}	Low mass prefab °C	Precast dorm °C
1	22.9	0.00	0.00	0.53	25.2	30.1
2	22.4	0.00	0.00	0.53	24.3	29.8
3	21.9	0.00	0.00	0.52	23.6	29.6
4	21.4	0.00	0.00	1.06	22.9	29.5
5	20.8	0.07	0.07	1.27	22.2	29.2
6	20.5	0.27	0.20	0.40	22.0	28.9
7	20.6	0.48	0.20	0.64	22.2	28.8
8	21.6	0.67	0.21	0.45	23.7	28.8
9	24.1	0.84	0.18	1.08	25.6	28.8
10	26.7	0.96	0.18	0.57	27.9	28.8
11	28.9	1.02	0.19	0.92	29.8	28.9
12	30.6	1.01	0.24	1.20	31.8	29.3
13	32.0	0.88	0.15	1.38	32.8	29.8
14	32.9	0.82	0.13	1.57	33.9	30.1
15	34.2	0.64	0.10	1.77	34.6	30.3
16	34.4	0.42	0.07	1.65	34.6	30.7
17	34.1	0.21	0.03	2.01	34.5	30.8
18	32.7	0.04	0.02	1.89	33.4	30.9
19	20.9	0.00	0.00	1.86	32.1	30.8
20	27.6	0.00	0.00	1.94	30.3	30.5
21	26.1	0.00	0.00	1.92	28.8	30.4
22	25.1	0.00	0.00	1.18	27.6	30.4
23	24.2	0.00	0.00	1.09	26.6	30.1
24	23.5	0.00	0.00	0.81	25.8	30.3

Table 2. Measured verification data for the period 25/07/88 to 01/08/88. Windows were open during the night from 20.00 h to 08.00 h

	Environmental data				Indoor temps	
Hour	Outdoor temp °C	Global radiation kW m^{-2}	Diffuse radiation kW m^{-2}	Wind speed m s^{-1}	Low mass prefab °C	Precast dorm °C
1	23.0	0.00	0.00	0.27	23.3	27.8
2	22.4	0.00	0.00	0.29	22.4	26.8
3	21.9	0.00	0.00	0.28	21.9	26.5
4	21.3	0.00	0.00	0.33	21.3	26.2
5	21.0	0.02	0.02	0.34	21.1	26.2
6	20.7	0.17	0.10	0.32	20.9	26.2
7	21.0	0.37	0.11	0.35	21.8	26.3
8	22.7	0.61	0.14	0.23	23.3	27.0
9	25.3	0.82	0.17	0.56	25.1	27.4
10	27.4	0.95	0.18	0.77	27.8	27.8
11	29.7	1.01	0.18	0.89	29.8	28.0
12	31.4	1.01	0.16	1.14	31.8	28.3
13	32.7	0.93	0.14	1.36	32.9	28.9
14	33.6	0.77	0.12	1.59	34.0	29.3
15	34.6	0.61	0.08	1.69	34.6	29.7
16	35.0	0.39	0.05	1.78	34.8	29.9
17	34.3	0.19	0.02	1.98	34.8	30.2
18	32.1	0.02	0.01	1.90	33.7	30.3
19	29.2	0.00	0.00	2.52	31.8	30.1
20	26.6	0.00	0.00	2.48	28.3	28.8
21	24.5	0.00	0.00	2.13	26.6	28.3
22	24.2	0.00	0.00	1.70	25.4	28.3
23	23.4	0.00	0.00	1.23	24.7	28.3
24	22.9	0.00	0.00	0.65	23.9	28.2

Table 3. Measured verification data for the period 01/08/88 to 08/08/88. Windows were open 24 hours of the day

Hour	Environmental data				Indoor temps	
	Outdoor temp °C	Global radiation kW m^{-2}	Diffuse radiation kW m^{-2}	Wind speed m s^{-1}	Low mass prefab °C	Precast dorm °C
1	22.4	0.00	0.00	0.51	23.5	27.1
2	21.9	0.00	0.00	0.44	22.8	26.9
3	21.4	0.00	0.00	0.49	22.3	26.7
4	21.0	0.00	0.00	0.30	21.9	26.2
5	20.4	0.01	0.01	0.35	21.6	26.1
6	20.1	0.02	0.02	0.33	21.8	25.8
7	21.1	0.14	0.09	0.34	22.1	26.1
8	22.9	0.33	0.13	0.39	23.8	26.4
9	25.5	0.57	0.17	0.64	25.6	26.8
10	27.7	0.76	0.19	0.84	27.9	27.3
11	29.1	0.90	0.22	1.27	29.5	27.9
12	30.3	0.98	0.21	1.29	31.1	28.7
13	31.9	0.99	0.20	1.54	31.9	29.4
14	32.9	0.84	0.17	1.79	32.8	29.8
15	33.4	0.78	0.16	1.96	33.3	30.3
16	32.9	0.60	0.12	2.03	32.7	30.5
17	32.3	0.40	0.07	2.28	31.9	30.0
18	31.0	0.18	0.03	2.66	30.6	29.4
19	27.8	0.03	0.01	3.00	28.8	28.6
20	26.5	0.00	0.00	2.50	26.6	27.3
21	25.0	0.00	0.00	2.18	25.8	27.1
22	24.2	0.00	0.00	1.97	25.0	26.8
23	23.5	0.00	0.00	1.07	24.3	27.0
24	22.9	0.00	0.00	0.52	24.0	27.3

08.00 h the next day. Windows were kept open 24 hours a day for the third period given in Table 3. The shutters in front of the windows were left in the open position for all the cases except for the low mass building with closed windows. For this case the shutters were also closed.

4. ANALYSIS OF DESERT BUILDINGS

4.1. *Comparison between measurements and predictions*

Simulation for the hourly indoor air temperatures in both buildings was carried out with the thermal model and newly proposed ventilation model described in Section 2.2. The construction of the low mass prefabricated unit differs from buildings previously analyzed as it possesses a high thermal resistance combined with a low thermal mass. Results for this low mass unit are shown in Figs 9 to 11. All three figures show good comparisons between measurements and predictions. Irrespective of the window operation the indoor temperature tends to follow the outdoor temperature fairly closely. Figures 12 to 14 show the results achieved for the precast concrete unit. For design purposes the comparison between measurements and predictions is acceptable. Indoor temperatures are fairly constant but the effect of ventilation due to different window operation is clearly visible.

The indoor air temperature swings encountered in both buildings vary from approximately 1.5 to 14°C. In the thermal model the temperature swing is primarily a function of the thermal storage as well as the ventilation rates. The comparison between the temperature swings thus seems to validate both the simulation of thermal storage and the ventilation rates for these two buildings.

4.2. *Investigating different ventilation strategies*

With the accuracy of the method proven, it is now possible to investigate different ventilation strategies. Figures 15 and 16 show respectively indoor air temperature predictions for the low mass fabricated building and the precast dormitory unit. To facilitate a comparison between different window operations, all the predictions are made using the outdoor climate specified in Table 1. From Fig. 15 it is clear that for the low mass prefabricated building no major advantage is achieved
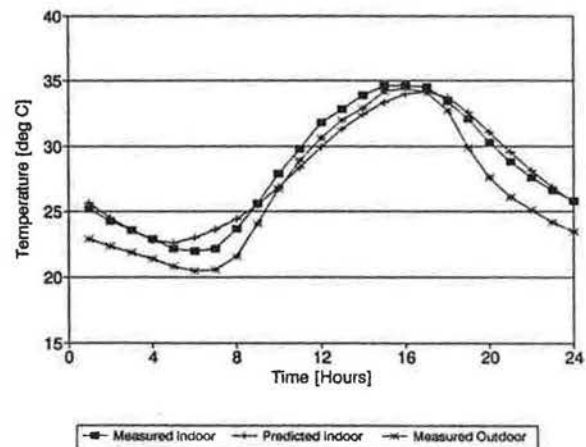

Fig. 9. Comparison between indoor air temperature predictions and measurements for low mass prefabricated unit. Windows were closed 24 hours of the day. Period of measurements 11/07/88 to 18/07/88.
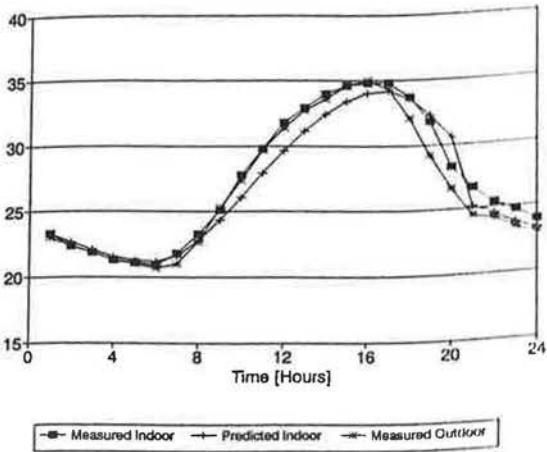
Fig. 10. Comparison between indoor air temperature predictions
and measurements for low mass prefabricated unit. Windows
were open during the night from 20.00 h to 08.00 h. Period of
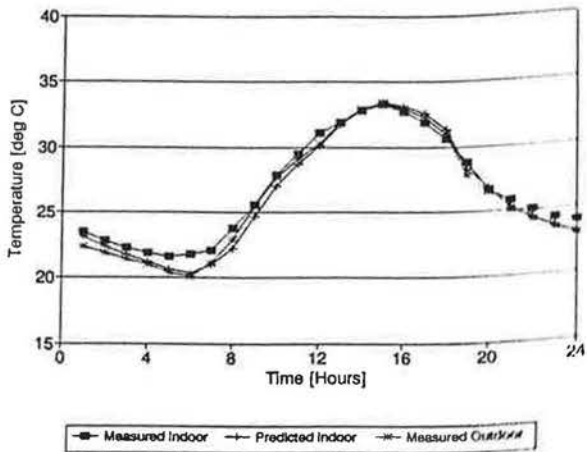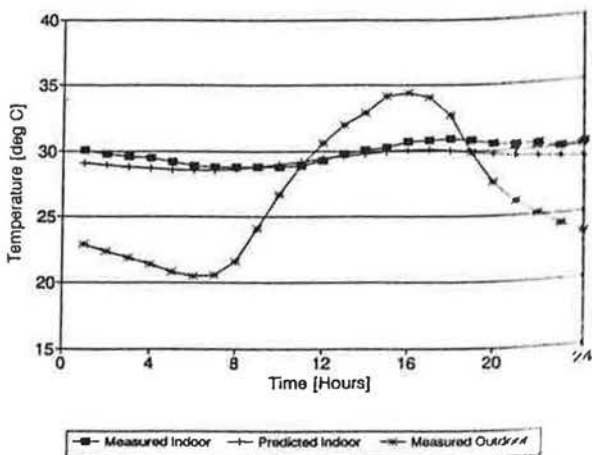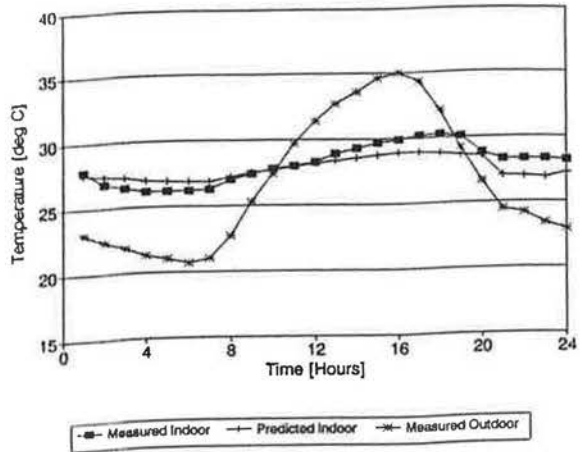measurements 25/07/88 to 01/08/88.

Fig. 13. Comparison between indoor air temperature predictions
and measurements for precast concrete unit. Windows were open
during the night from 20.00 h to 08.00 h. Period of measurements
25/07/88 to 01/08/88.

Fig. 11. Comparison between indoor air temperature predictions
and measurements for low mass prefabricated unit. Windows
were open 24 hours of the day. Period of measurements 01/08/88
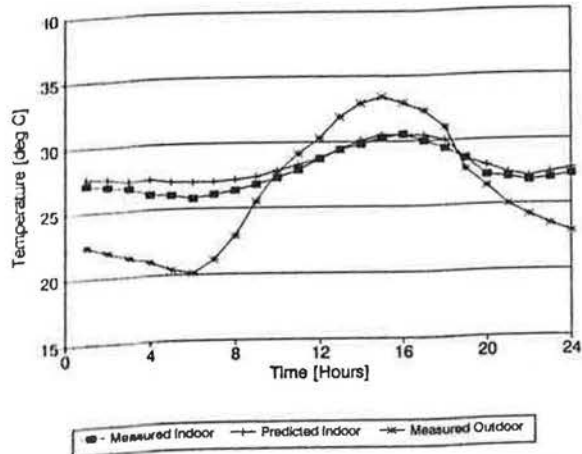to 08/08/88.

Fig. 14. Comparison between indoor air temperature predictions
and measurements for precast concrete unit. Windows were
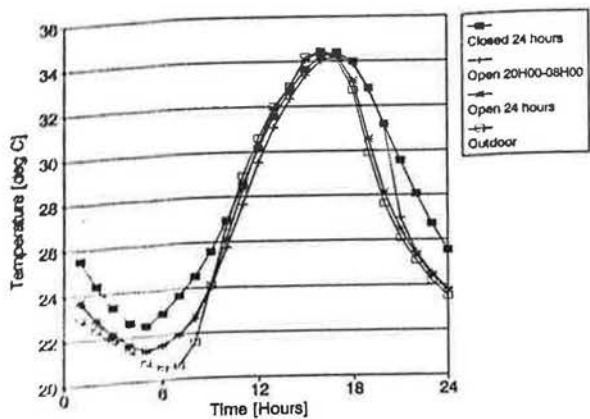open 24 hours of the day. Period of measurements 01/08/88 to
08/08/88.

Fig. 12. Comparison between indoor air temperature predictions
and measurements for precast concrete unit. Windows were
closed 24 hours of the day. Period of measurements 11/07/88 to
18/07/88.

Fig. 15. Indoor air temperature predictions for low mass pre-
fabricated unit employing 3 different window operations. All
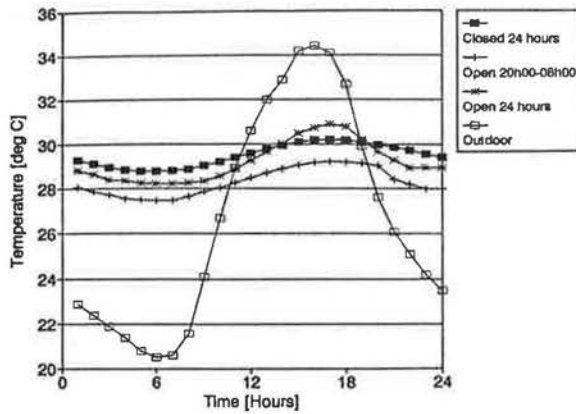three predictions employ environmental data from Table 1.

Fig. 16. Indoor air temperature predictions for precast concrete unit employing 3 different window operations. All three predictions employ environmental data from Table 1.

by opening and closing the windows for certain hours of the day. In this building the indoor air temperatures follow the outdoor air temperature fairly closely, no matter whether the windows are open or closed. A more pronounced effect on the indoor air temperature of the precast dormitory unit is however discerned when considering Fig. 16. The mean indoor air temperature is reduced in the order of 1.5°C if the windows are open during the night and closed during the day. This night cooling effect is possible because of the building's higher storage capabilities. Keeping the windows open during the day increases the maximum indoor temperature by approximately 2°C. It must however be noted that dry-bulb temperatures are discussed here and not comfort temperatures. The increased ventilation due to open windows during the day might achieve a better comfort temperature. However, the comfort temperature can be determined fairly accurately by employing the predicted dry-bulb temperature.

When designing naturally ventilated buildings it is important to investigate different ventilation strategies as above. The success of investigations will however largely depend on the reliability of ventilation estimates and the ability to accurately simulate the effect of ventilation. The study performed for this paper showed that the proposed ventilation model and the simplified thermal procedure, addressed these aspects successfully. Incorporating ventilation estimates from the proposed ventilation model in the simplified thermal procedure thus seems to have large potential for design purposes.

5. CONCLUSIONS

This joint publication describes a verification study carried out by the Jacob Blaustein Desert Architecture unit in Israel and the Centre for Experimental and Numerical Thermoflow in South Africa. Independent measurements in buildings in the Negev Desert were used to verify a thermal model and a ventilation prediction method developed in South Africa. The buildings differed from previous verification studies in that they are situated in the Northern Hemisphere and are very well insulated. The comparisons achieved gave an acceptable level of confidence in the employed prediction procedures. Information and data for the verification of the buildings in the Desert are given in detail to facilitate verification procedures by other researchers.

A new method to predict ventilation rates with limited data for buildings of simple design was proposed. This method was used to determine time varying ventilation rates needed for the verification of the thermal simulations.

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