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METEOROLOGICAL GUIDLINES FOR OPTIMAL ORIENTATION OF BUILDINGS IN THE NEGEV SEMI-ARID CONDITIONS

DOV SKIBIN and CHAYA NOAH
Ben-Gurion University of the Negev, Israel

INTRODUCTION

It is well known that the meteorologically comfort conditions for the human body are within limited ranges of temperature, humidity and vintilation. Many discomfort indices and chill factors were developed, enabling quantitative identificatoin of the desired and undesired ranges of these parameters and their combinations (e.g. Landsberg, 1968; Munn, 1970).

The microclimate inside a building is strongly influenced by the heat fluxes through the walls, floor, ceiling and windows, by the outdoor meteorology and by the exchange of air through the doors, windows, etc. Considering a standard opening, the latter factor is a function of the orientation of the opening, relative to the wind direction and (to a lesser extent) of the wind speed. Givoni (1965) analyzed the orientation problem and recommended further research of the problem, since complete guidelines would not be obtained at that time.

The purpose of the present paper is to determine the orientation of buildings and their openings in Beer Sheva, that will optimize the interior microclimate. The optimization takes into account local meterological factors, such as wind direction and speed, termperature, humidity, rain and dust storms.

Solar radiation for instance is not incorporated into this context since its influence varies with the position of the particular appartment in the block, the floor in which it is situated, and the thermal mass of the structure, as well as other factors which cannot be treated universally to provide a certain optimum.

The meteorology and climatology of Beer Sheva have been throughly investigated (e.g. Skibin, 1974; Givoni, 1979). However, such information is generally insufficient for architects and planner who cannot rely on meteorological analysis but require clear-cut recommendations and guidelines for planning puropses. The present paper attempts to partially bridge this gap.

METHODOLOGY, DATA AND RESULTS

Meteorological observations of the Beer Sheva synoptic station for eight years

Table 1: Accumulated Frequency Distribution of Low Temperatures in the Winter in Beer Sheva as a Function of the Hour: Average Relative Humidity and Average Wind Speed as a Function of the Temperature.

Temp. (°C)	Hour (L.T.) 2	5	8	11	14	17	20	23	Average Rel. Hum. (%)	Average wind speed (Knots)
0	0.	0.2	0.	0	0.	0.	0.	0.	85	3.0
1	0.2	0.4	0.	0.	0.	0.	0.	0.	81	4.0
2	0.4	0.9	0.4	0.	0.	0.	0.	0.4	79	6.5
3	1.4	4.2	0.9	0.	0.	0.	0.2	0.9	83	5.6
4	5.4	10.1	1.9	0.2	0.2	0.2	0.4	1.9	85	6.1
5	11.6	20.6	4.4	0.5	0.3	0.5	1.4	5.2	86	5.5
6	23.5	32.5	10.1	0.7	0.5	1.0	3.3	12.2	84	4.9
7	39.6	47.4	22.2	1.6	1.4	1.7	7.0	23.6	83	5.3
8	54.1	60.1	37.2	2.9	1.6	3.0	14.0	40.6	80	5.3
9	66.7	72.6	53.0	4.5	2.4	4.7	28.8	58.2	77	5.8
10	79.5	83.2	66.6	6.6	4.0	9.3	44.4	71.2	76	6.0
11	85.6	89.0	78.8	11.7	8.4	16.4	61.7	80.8	72	6.6
12	91.9	93.0	87.1	19.2	14.1	28.3	75.5	88.5	68	7.1
13	95.3	95.1	91.1	30.6	20.4	40.6	84.6	93.0	63	7.4
14	96.3	97.0	93.7	44.6	30.2	55.4	90.4	95.6	57	7.8
15	97.4	98.6	95.8	57.0	40.5	68.2	94.8	97.4	54	7.7
16	98.4	98.8	97.6	69.2	52.2	80.4	96.5	97.9	48	7.8
17	98.9	99.3	97.9	77.6	62.8	87.8	97.6	98.8	46	7.8
18	98.8	99.7	98.6	83.4	73.1	91.8	98.6	99.0	42	7.7

Source: compiled by author from file data of Israeli Meteorological Service.

Table 2: Accumulated Frequency Distribution of High Temperatures in the Summer in Beer Sheva as a Function of the Hour; Average Relative Humidity and Average Wind Speed as a Function of the Temperature

Temp (°C)	Hour (L.T.) 2	5	8	11	14	17	20	23	Average Rel. Hum. (%)	Average wind speed (knots)
28	0.2	0.	1.9	63.1	90.0	55.2	2.1	0.2	42	9.2
29	0.	0.	1.9	43.6	82.7	36.4	1.0	0.2	40	9.4
30	0.	0.	1.2	29.0	68.0	22.1	0.9	0.	37	9.7
31	0.	0.	0.7	17.3	51.7	13.1	0.6	0.	33	9.3
32	0.	0.	0.3	10.5	35.4	7.5	0.3	0.	31	9.5
33	0.	0.	0.	5.5	21.2	3.8	0.2	0.	28	9.8
34	0.	0.	0.	3.4	12.0	2.7	0.2	0.	26	9.2
35	0	0.	0.	2.2	6.8	1.4	0.2	0.	21	9.7
36	0.	0	0.	1.1	3.8	0.9	0.	0.	18	9.1
37	0	0.	0.	0.9	2.4	0.7	0.	0.	21	9.7
38	0	0	0	0.5	1.4	0.3	0.	0.	14	8.3
39	0.	0	0.	0.2	0.7	0.2	0.	0.	10	7.3
40	0.	0.	0	0.	0.3	0.	0.	0.	12	11.2
41	0	0.	0.	0	0.2	0.	0.	0.	9	9.0

Source: Compiled by author from file data of Israel Meteorological Service were used in this study (18,772 measurements during 1964—72). The data were obtained by courtesy of the Israeli Meteorological Service. The methodology of this paper is based on two stages. In the first stage, the temperature and

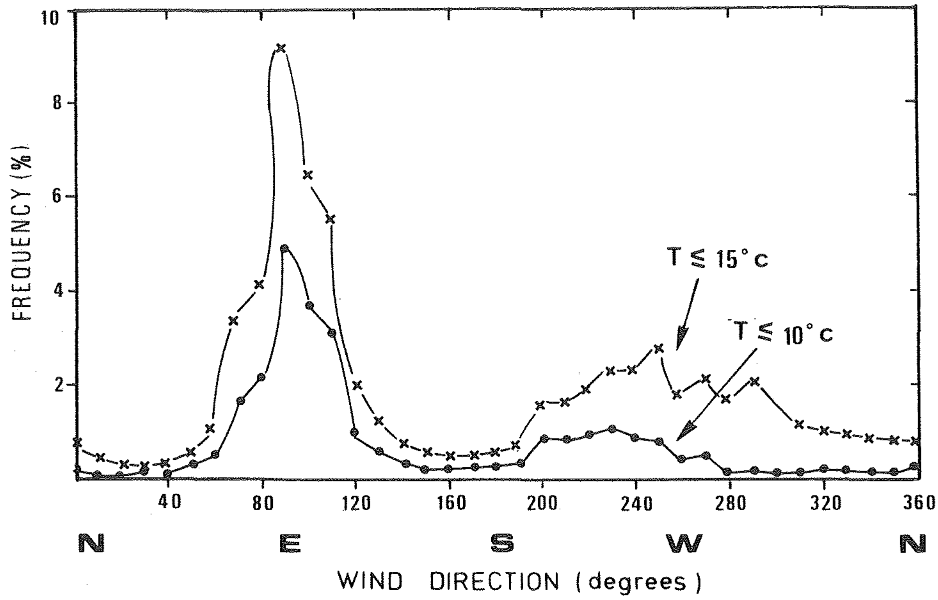

Fig.1: Frequency distribution of wind direction in Beer-Sheva in the cases where the temperature was below 15°C and 10° C.

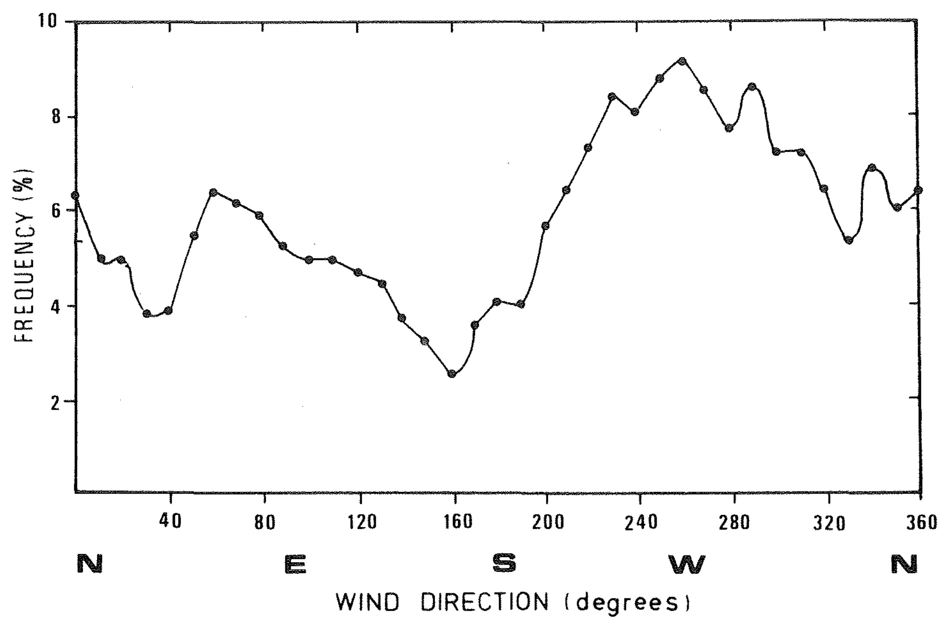

Fig.2: Distribution of the average wind speed when T ≤ 15°C in Beer Sheva, as a function of the wind direction

humidity data are analysed in order to determine the degree to which discomfort conditions due to cold or hot humid weather are a major problem requiring a solution through proper planning, for instance. Then, the distribution of the discomfort conditions, as well as rain and dust storm events, as a function of wind direction are analysed in order to derive the optimum orientation of the buildings.

Tables 1 and 2 present the fraction of the time (in percentage) during which the air temperature is below (or above) a certain temperature, as a function of the hour, during winter and summer, respectively. The last two columns show the average relative humidity and average wind speed as function of the hour, during winter and summer, respectively. Fig. 1 illustrates the frequency distribution of low temperature events as function of the wind direction, for the cases $T < 15°C$ and $T < 10°C$, while Fig. 2 illustrates the azimuthal distribution of the average wind speed in the events where the temperature was 15°C or below. The frequency distribution of events of rain and dusty atmosphere (visibility 5 Km. or less) as function of the wind direction in those case, are given in Figs. 3 and 4 respectively.

Tenenbaum et. al. (1961) suggested the average of the dry and wet bulb temperature as a discomfort index for hot-humid conditions. This index was adopted by the Israeli Meteorological Service. Medium and high discomfort are announced when this index is 24°C or more. Fig. 5 illustrates the frequency distribution of this index as a function of the wind direction.

To complete the meteorological picture, Tables 3 and 4 present the distribution in Beer-Sheva as a function of month and hour and the month, respectively. The values are the percentage of cases in the measurement period and the lines are the analyzed isopleths of the frequency.

DISCUSSION

The semi-arid climate of Beer-Sheva is demonstrated in Tables 1 and 2. During 73 percent of the winter time (table 1) the temperature is below 9°C at 5 p.m. and below 18°C at 2 a.m. In summer (Table 2) the temperature is never above 28°C at 5 p.m., but it is 50 percent of the time above 31°C at 2 p.m. The average daily amplitude of the temperature in Beer-Sheva was computed and found to be between 7.1°C during midwinter and 13.7°C in midsummer. Taking into account that Beer-Sheva is only 45 km. from the Mediterranean sea shore, its climate is relatively an extreme one. Buildings should therefore be planned so as to provide both minimum penetration of cold during the winter and maximum ventilation during the summer.

Consider first the cases of low temperature. Fig. 1 indicates two peaks — during easterly and southwesterly flow. Table 2 shows that these wind directions are more frequent during the winter than in summer. From Table 4 it is evident that easterly flow is more frequent during the night, compared to the southwest wind, which is more frequent during the day. The reason for this is (Skibin, 1979; Skibin and Hod, 1979) that east wind in Beer-Sheva results mainly from the nocturnal downslope land breeze flow towards the warm Mediterranean Sea (Skibin, 1974). Winds from the southwest usually result from the synoptic Cyprus low pressure system. The difference between these flows is evident also in Fig. 2, indicating that the east wind is lighter due to the thermal stability at night. The southwest wind is on the average 50 percent stronger than the east wind. It is therefore important in Beer-Sheva to reduce the number and area of openings directed towards the southwest.

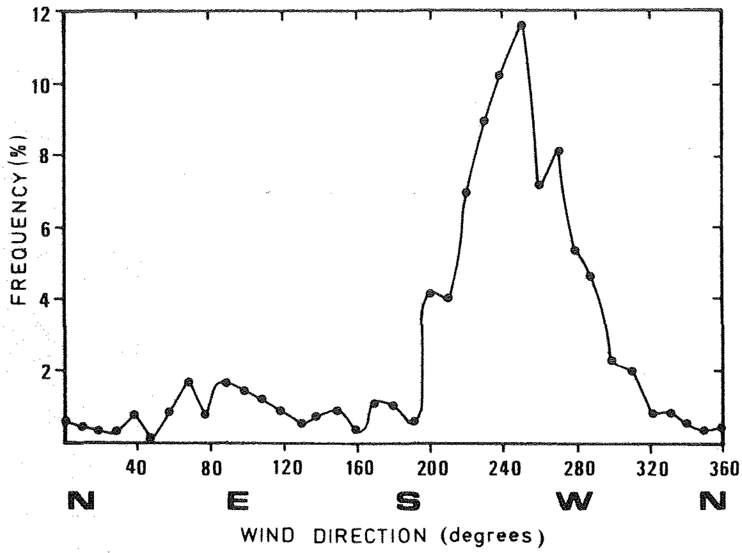

Fig. 3: Frequency distribution of wind direction in the cases of rain in Beer Sheva.

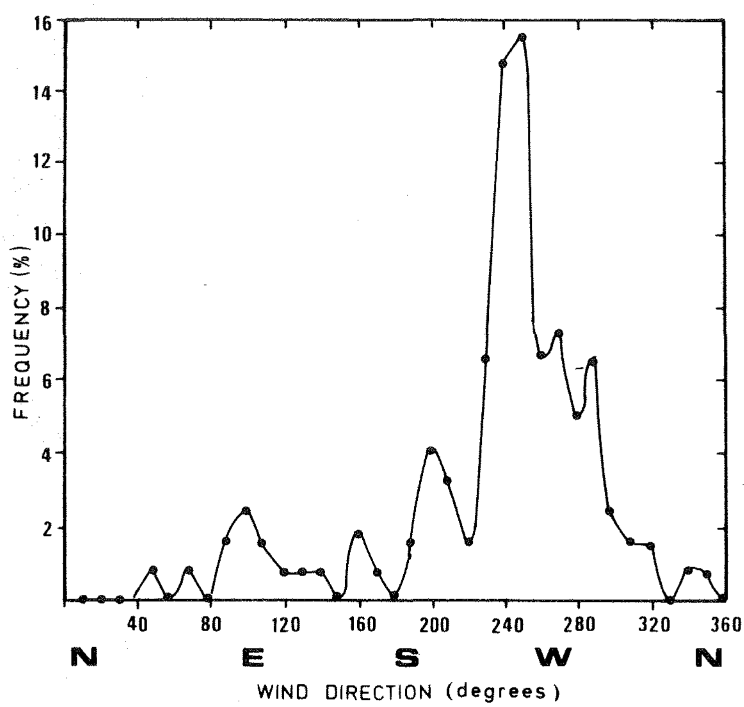

Fig. 4: Frequency distribution of wind direction for dusty atmosphere cases (visibility below 5 km.)

Table 3: Frequency (precentage) of Wind Direction in Beer Sheva as Function of the Month. Lines are Isopleths of Frequency (0.1, 1, 2, 5 and 10 Percent.)

Wind Direction (digrees)	Month 1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
10	0.2	0.5	0.6	0.8	0.2	0.3	0.3	0.3	0.5	0.4	0.8	0.3	5.4
20	0.2	0.2	0.3	0.3	0.5	0.1	0.1	0.2	0.3	0.4	0.6	0.1	3.3
30	0.1	0.3	0.2	0.2	0.2	0.1	0.0	0.1	0.2	0.2	0.1	0.1	1.8
40	0.2	0.6	0.2	0.4	0.3	0.1	0.0	0.1	0.1	0.3	0.5	0.2	2.8
50	0.8	1.2	0.2	0.4	0.4	0.1	0.2	0.1	0.1	0.3	0.7	0.5	5.1
60	1.5	1.8	0.9	1.4	0.6	0.4	0.1	0.3	0.5	0.7	2.5	1.1	11.7
70	2.3	4.1	2.7	1.9	2.0	1.0	0.6	1.1	1.6	2.4	4.5	4.4	28.3
80	5.2	3.5	3.7	2.4	1.8	1.4	0.9	1.7	1.3	3.1	3.2	3.9	32.0
90	10.7	9.0	6.6	6.6	3.8	2.9	1.2	2.0	3.5	5.8	9.0	10.8	71.1
100	6.4	7.1	4.7	4.7	3.0	2.1	1.3	2.0	2.5	4.3	5.6	7.7	50.9
110	6.6	6.7	5.4	4.4	2.1	1.4	0.5	0.8	1.2	3.8	5.8	6.4	44.6
120	2.7	2.1	2.4	2.1	1.2	0.5	0.1	0.3	0.8	1.3	2.1	2.4	18.0
130	2.3	1.6	2.0	1.3	0.7	0.3	0.1	0.0	0.3	0.5	1.3	1.2	11.7
140	0.8	1.1	1.1	1.0	0.4	0.4	0.2	0.1	0.0	0.3	0.4	0.9	6.8
150	0.7	0.8	0.5	0.7	0.6	0.3	0.0	0.0	0.1	0.3	0.4	0.8	5.2
160	0.4	0.2	0.8	0.7	0.3	0.0	0.1	0.1	0.2	0.3	0.5	0.7	4.3
170	0.7	0.5	0.6	0.6	0.4	0.1	0.1	0.1	0.0	0.2	0.1	0.6	3.8
180	0.6	0.7	0.8	0.8	0.5	0.2	0.1	0.3	0.0	0.1	0.8	1.2	6.1
190	1.1	0.4	0.6	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.2	1.1	4.3
200	3.0	1.6	1.4	0.8	0.5	0.6	0.3	0.3	0.2	1.0	1.1	2.9	13.5
210	2.1	1.9	1.3	0.3	0.6	0.5	0.4	0.4	0.3	0.5	1.3	2.8	12.3
220	3.0	2.3	1.5	1.3	0.7	0.5	0.8	0.4	0.3	1.2	1.5	2.6	15.9
230	3.2	2.5	2.5	1.1	0.5	1.2	1.0	0.8	0.3	0.6	1.4	3.8	18.8
240	3.4	2.6	3.0	1.2	1.2	1.3	2.0	0.9	0.6	0.7	1.7	3.4	22.2
250	4.5	2.6	4.2	2.0	1.2	1.6	2.2	1.1	0.6	0.6	1.6	2.9	25.3
260	2.7	2.2	1.8	2.2	1.1	1.9	2.0	1.1	0.6	1.1	1.5	1.5	19.9
270	2.9	2.9	3.4	2.7	2.4	3.8	3.7	3.0	2.2	1.4	1.6	2.4	32.8
280	1.5	2.7	3.0	3.6	4.2	4.0	5.2	3.7	2.9	2.3	1.3	1.3	36.1
290	2.0	3.7	3.8	5.6	5.0	6.6	8.0	7.7	5.0	3.1	2.4	2.1	55.8
300	1.2	2.7	3.6	4.3	5.2	7.1	6.8	8.7	6.2	3.5	1.8	0.9	52.6
310	0.6	1.8	2.5	3.6	6.2	5.5	9.0	7.7	7.7	4.7	2.6	1.2	53.0
320	0.9	1.4	2.1	3.3	5.8	6.2	6.6	7.4	6.7	5.4	3.7	1.1	50.6
330	1.1	1.5	2.4	3.7	7.6	7.0	4.7	4.9	6.4	5.1	2.4	0.7	48.2
340	0.3	1.4	2.2	3.0	4.6	3.6	1.3	2.4	3.0	3.8	2.1	0.7	29.1
350	0.8	1.8	1.8	2.1	2.6	1.4	1.2	1.1	2.3	2.2	1.4	0.8	19.7
360	0.5	1.2	1.6	1.6	1.8	0.9	0.6	0.4	1.2	1.6	1.0	0.7	13.4
VARIABLE	6.2	7.6	6.8	7.4	12.9	17.1	21.6	21.8	23.5	19.6	13.8	7.3	163.6

Source: Compiled by auther after Skibin, 1979.

This conclusion is in accordance with the distributions in Fig. 3 and 4, showing that most cases of rain and dust occur when the wind blows from the southwest-west direction. Buildings with minimum opening in this direction are, therefore, advantageous with respect to reduction of the penetration into them of cold, rain and dust.

Let us now turn to the events of medium and high discomfort due to hot humid conditions. Fig. 5 shows that these conditions occur when the wind is coming from the Mediterranean Sea, leas than 50 km North-west of Beer Sheva. From Tables 3 and 4 it can be seen that northwesterly winds are more frequent during the summer and in the afternoon hours. The very pronounced single peak in Fig.

Table 4: Frequency (precentage) of Wind Direction in Beer Sheva by Hours. Lines are Isopleths of Frequency (0 1,1,2,5 and 10 Precent)

Wind Direction (digrees)	Hours (L.T.) 2	5	8	11	14	17	20	23	TOTAL
10	0.4	0.3	0.3	0.6	0.4	0.8	2.3	0.3	5.4
20	0.2	0.1	0.4	0.6	0.6	0.2	0.5	0.3	3.3
30	0.3	0.0	0.3	0.3	0.1	0.3	0.4	0.0	1.8
40	0.4	0.4	0.2	0.4	0.1	0.4	0.8	0.2	2.8
50	0.7	1.2	0.7	0.6	0.1	0.5	0.8	0.5	5.1
60	2.1	1.9	1.7	0.5	0.7	1.0	1.8	2.1	11.7
70	7.0	9.3	3.0	0.7	0.9	0.9	2.2	4.2	28.3
80	8.2	10.3	4.5	0.5	0.6	0.7	2.4	4.8	32.0
90	15.8	20.1	13.9	2.5	1.9	1.4	4.6	10.9	71.1
100	11.1	13.3	10.[illegible]	2.6	1.6	1.5	3.6	6.7	50.9
110	7.0	10.5	10.6	4.3	2.4	1.3	2.2	5.9	44.6
120	2.7	2.9	4.4	3.1	1.5	0.6	1.0	1.8	18.0
130	1.2	1.9	2.2	2.9	1.4	0.5	0.5	1.2	11.7
140	0.5	1.1	1.4	1.1	1.1	0.3	0.6	0.8	6.8
150	0.3	0.4	1.2	1.4	0.6	0.2	0.4	0.6	5.2
160	0.5	0.7	0.6	0.8	0.5	0.0	0.5	0.5	4.3
170	0.4	0.5	0.6	0.8	0.5	0.0	0.3	0.6	3.8
180	0.5	0.8	1.6	1.5	0.7	0.2	0.2	0.6	6.1
190	0.6	0.7	0.6	0.7	0.4	0.2	0.0	1.0	4.3
200	2.7	3.0	2.8	1.8	1.2	0.3	0.6	1.2	13.5
210	1.8	2.7	2.7	2.6	1.0	0.1	0.6	0.8	12.3
220	1.8	2.1	3.7	3.6	1.9	0.6	0.9	1.3	15.9
230	2.6	2.8	3.2	3.9	2.4	1.3	1.0	1.5	18.8
240	2.2	1.6	4.2	5.9	3.6	0.7	1.3	2.7	22.2
250	2.8	2.1	3.4	6.3	4.5	2.0	2.0	2.1	25.3
260	1.6	1.3	2.3	5.3	4.5	1.3	1.3	2.3	19.9
270	1.5	1.2	3.2	10.0	8.3	3.2	2.1	3.4	32.8
280	1.8	1.0	2.7	8.6	9.3	4.4	4.3	4.0	36.1
290	1.4	0.8	2.5	9.8	16.7	12.4	6.6	5.6	55.8
300	0.9	0.5	2.0	9.0	14.4	12.5	9.8	3.4	52.6
310	0.7	0.3	1.8	6.8	11.4	18.7	11.3	2.0	53.0
320	0.8	0.4	1.1	6.3	10.9	17.6	11.3	2.1	50.6
330	0.6	0.4	1.9	4.7	10.0	17.7	11.0	1.8	48.2
340	0.6	0.4	1.2	2.5	4.3	10.4	7.7	2.0	29.1
350	0.5	0.4	1.1	2.3	2.7	5.5	6.2	1.0	19.7
360	0.4	0.2	1.0	2.6	1.4	2.2	4.3	1.3	13.4
VARIABLE	40.5	27.2	24.8	7.0	0.5	2.9	17.0	43.7	163.6

Source: Compiled by author after Skibin, 1979

5 leads to the inevitable conclusion that it is essential to ensure maximum ventilation in Beer Sheva especially in these cases This can be achieved by building apartments with windows to the northwest (310°) and southeast (130°)

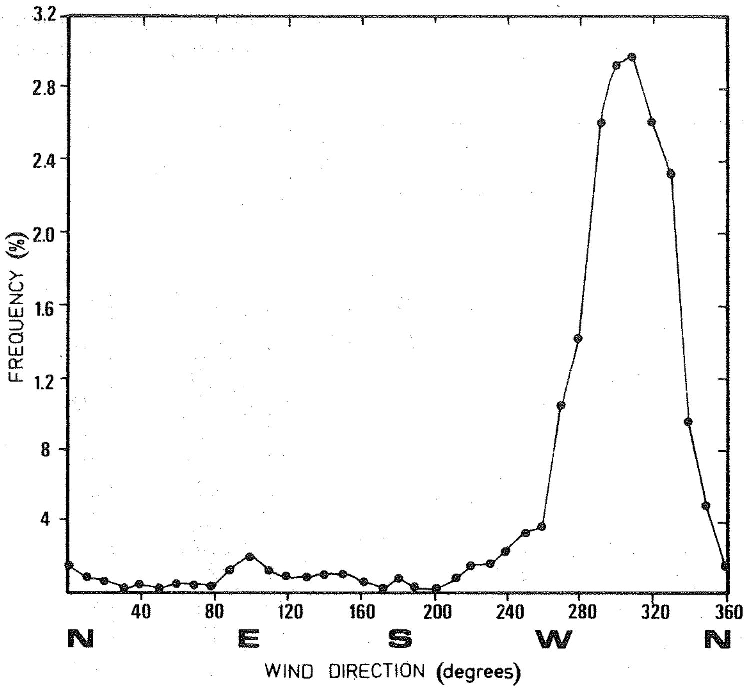

Fig. 5: **Frequency distribution of wind direction in the cases where the discomfort index was medium or high in Beer Sheva.**

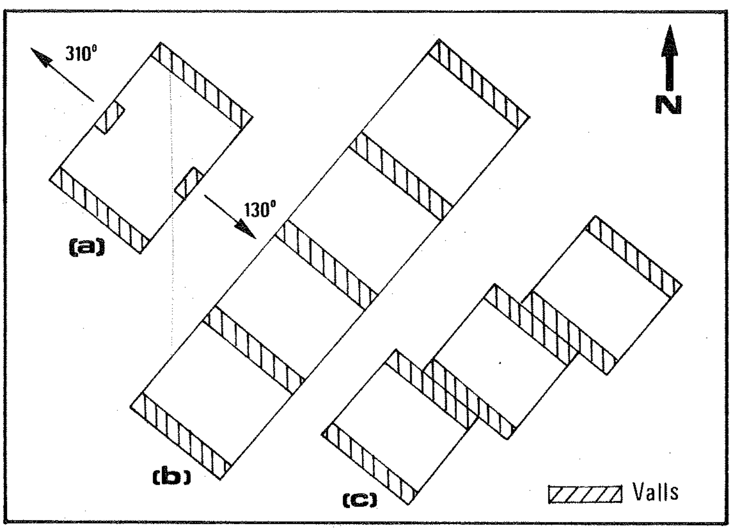

Fig. 6: **Schematic presentation of several configurations of buildings in the optimal orientation in Beer Sheva.**

directions. Fortunately it is possible to conform to all the above constraints. Opening to the north-west and southeast, and walls in the other directions will give maximum ventilation and will minimize the penetration of dust, rain and cold associated with the strong southwest wind. The low temperatures at night are associated with the east wind. Since it is relatively weak and coming at an angle of 30—40 degrees from the perpendicular to the southeast windows, its cooling effect on the interior climate is less important. Fig. 6 presents schematically possible arrangements of single houses and large apartment blocks, according to the above guidelines. Note that mutual shielding of adjacent apartments from the west-southwest and east-north-east directions can easily be obtained (Fig. 6(c)).

SUMMARY AND CONCLUSIONS

Several important factors determining the microclimate inside buildings in Beer Sheva were discussed and analyzed. These are: the azimuthal distribution of high and low temperatures, discomfort index, rain and dust storms as functions of wind direction. Based on findings of the analysis it is recommended that buildings in Beer Sheva will be built with maximum openings to the directions 310° and 130°, and minimum openings to the south-west. Adoption of these recommendations will maximize ventilation inside the buildings under the conditions when it is especially needed. At the same time this configuration will assist in minimizing penetration of dust and rain, as well as cold air, into the buildings.

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