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Determination of outdoor design parameters for arid zone-Waddan Libya: A case study

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ABSTRACT

Incorrect selection of outdoor parameters, such as temperature, can be costly when cooling and heating demand of domestic dwellings are considered. If extreme weather conditions are taken, uneconomical design and oversizing may result. In this paper prevailing weather data for Dry Bulb Temperature (DBT) and Relative Humidity (RH), for one year, were collected and graphically presented and analysed. The data were collected from a weather station situated at a Saharan Desert Oasis in the North East of Fezzan region of South West of Libya (Waddan city) for one complete year of 2007. The detailed analysis, which was carried out using Microsoft Excel software, has revealed that the dry bulb temperature range of 22 to 40°C and the relative humidity of 44% were suggested to be the outdoor design parameters that should be considered during design or selection of thermal systems in arid-zones. It has been also observed from the analysis of relative humidity curves that, during the day, the weather conditions of humid arid zone areas were completely different from the conditions at the night. Very humid and warm during the day and low-to-moderate humid and cold during the night for the entire year.

1. Introduction

The graphical presentation is a simple and direct way to analyse and interpret climatic data. The proper selection of climatic variables, especially Dry Bulb Temperatures (DBT), and their analysis can affect many designs and thermal systems, i.e. building load calculations, performance of the corresponding heating, ventilation and air-conditioning (HVAC) equipment, accuracy of heating energy consumption estimation, and any thermal exchange outdoor operating machines. According to the guides of ASHRAE handbook fundamentals (Ashrae, 1989) and before analysing weather data and assessing any design implications, it is important to determine the summer and winter months, which indicate the cooling and heating seasons, respectively. A general approach is to select 4 calendar months with a highest long-term monthly average (DBT) as the summer period, and three months with the lowest average (DBT) as the winter period. However, this approach of selecting these seasons may not be appropriate at different climatic zones and each climate zone has its own special characteristics.

2. Prevailing dry-bulb temperature and relative humidity

Prevailing weather data for Dry Bulb Temperature (DBT) and Relative Humidity (RH) for one year (2920 readings; 8 readings per day at 3 hrs. intervals) were collected and graphically analysed using Microsoft Excel software. The data were available for one year (2007) only from a weather station situated at Waddan city of Libya. The location is meteorologically classified as arid zones. Waddan is a Saharan desert oasis in the North-East of Fezzan region of South-West of Libya. It is in Al- Jufrah Baladiyat in the administrative system of Libya that was established in 1988. It is located 265 km south of Libyan North Coast. It has the global coordinates of 29°09′40″N 16°08′37″E. Figs. 1 and 2 show 2920 readings of distributed DBT and RH data points. In Fig. 1, the highest and lowest dry bulb, temperatures are 45°C and 1°C respectively. From an economical point of view, these temperatures are not accepted to be adopted as outdoor design temperatures.

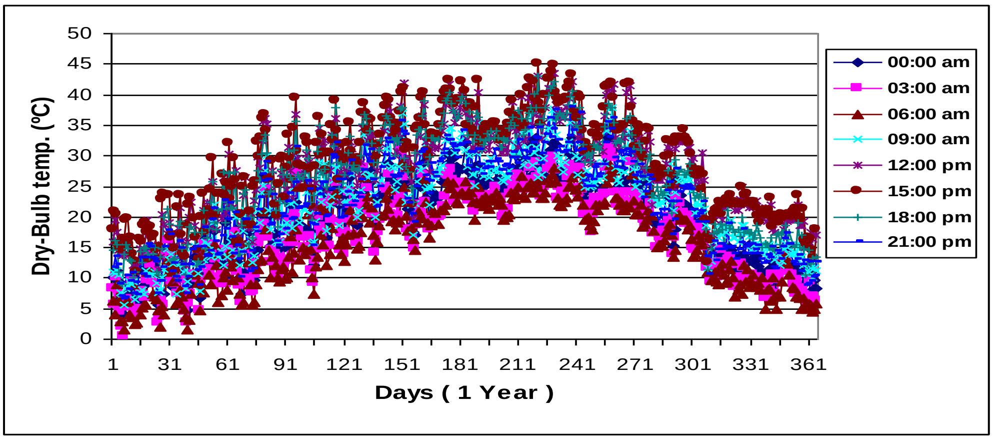

Fig 1. Dry-bulb temperature distributions for one-year 2920 readings (8 readings/day at 3 hrs. intervals)

The relative humidity readings in Fig. 2 are varied throughout the whole day of the entire year and they are approximately 12% at 12:00 AM and 90% at 6:00 PM. The typical humidity is nearly 50% when measured at 6:00 AM in both summer and winter seasons. Relative humidity is also found to vary between 10% and 60% at 12:00 AM and 6:00 AM respectively. At these times (12:00 AM and 6:00 AM), the lowest dry-bulb temperatures are recorded in the summer and in the winter seasons. The analysis of relative humidity curves shows that, during the day, the weather conditions of humid arid zones are completely different from the conditions at night, thus very humid and warm during the day and low-to-moderate humid and cold during night for the entire year. However, the average design humidity value for the entire year is found to be 44%.

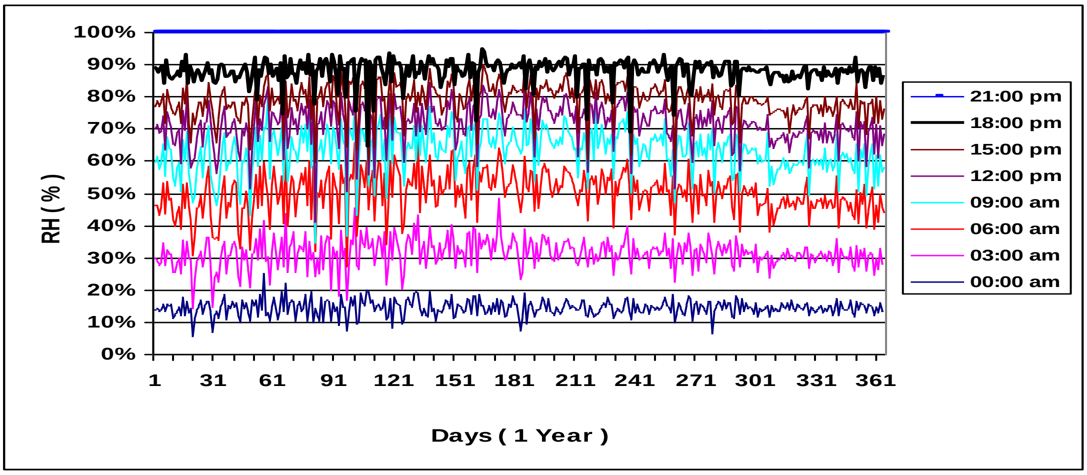

Fig. 2. Relative humidity distributions for one-year 2920 readings (8 readings/day at 3 hrs. intervals)

Monthly mean maximum dry-bulb temperature and monthly mean minimum dry-bulb temperature are graphically presented by bar charts as shown in Figs. 3 and 4 respectively.

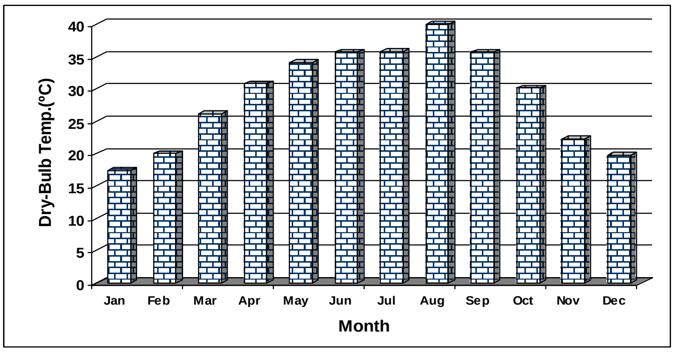

Fig. 3. Monthly mean maximum Dry-bulb temperature

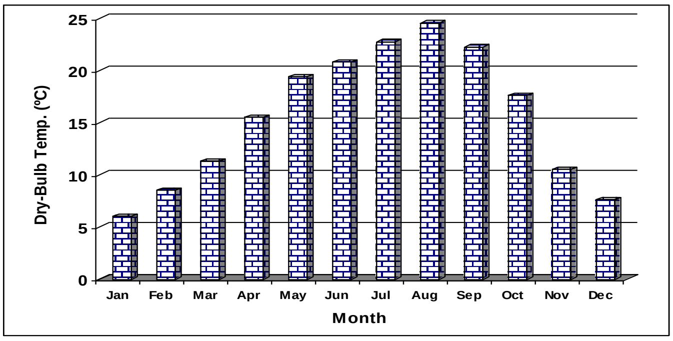

Fig. 4. Monthly mean minimum Dry-bulb temperature

Fig. 5 shows a graphical comparison between annual monthly mean maximum and mean minimum dry bulb temperatures in degrees centigrade. It is evident that August is the hottest month for both mean maximum and mean minimum dry bulb temperature, whereas January is the coldest month for both mean maximum and mean minimum DBT. During the entire year, the temperature difference (ΔT) is roughly constant between monthly mean maximum DBT in summer time and mean minimum DBT in winter times, and it is in the range of 12-15°C.

Dry-bulb temperature values are also presented in Fig. 6 to compare between daily mean DBT in August (hottest month) and daily mean DBT in January (coldest month). It can be seen that mean maximum DBT and mean minimum DBT are recorded at 3:00 PM and 6:00 AM respectively.

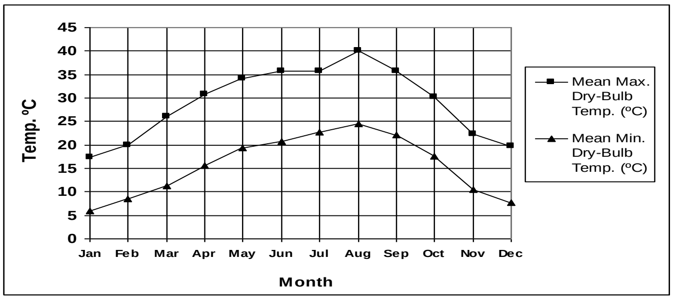

Fig. 5. Monthly mean maximum and mean minimum DBT

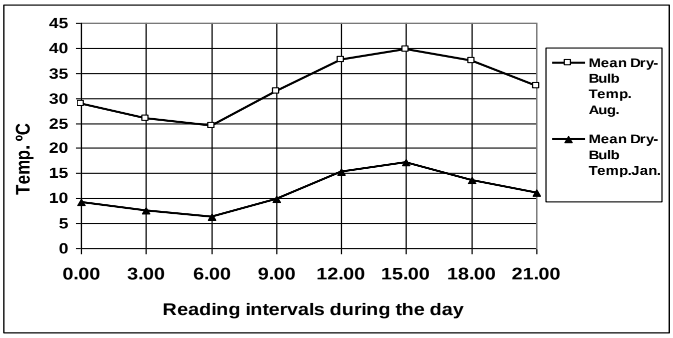

Fig. 6. Mean DBT distribution in January and August

3. Outdoor design conditions

Outdoor design temperatures, which indicate the extreme conditions of thermal load calculation of different systems, are the most important design parameters in building design and heat transfer plant equipment sizing (Holladay, 1973). The ASHRAE handbook fundamentals (Ashrae, 1989) suggested five different cumulative frequency levels at which outdoor design conditions are determined, namely 0.4%, 1%, 2%, 99% and 99.6%. The design temperature determined at, for example 0.4% of frequency level, is the temperature whose the outdoor temperature might exceed 0.4% of the time in a year. Selecting of frequency levels and hence the corresponding outdoor design temperatures are important and always based on considerations of the local design practices and any likely effects on overload capacity and operation. One of the main purposes of HVAC system is to provide an adequate thermal comfort levels for the occupants of a building. However, in thermal design conditions the usual practice is to determine the outdoor design conditions at 1% and 99% of frequency levels for summer cooling and heating load analysis respectively. As shown, clearly from the accumulative frequency curve in Fig. 7, the summer and winter outdoor dry-bulb design temperatures are found to be 40°C and 5-6°C corresponded to 99% and 1% respectively of cumulative frequency levels, as guided by ASHRAE handbook.

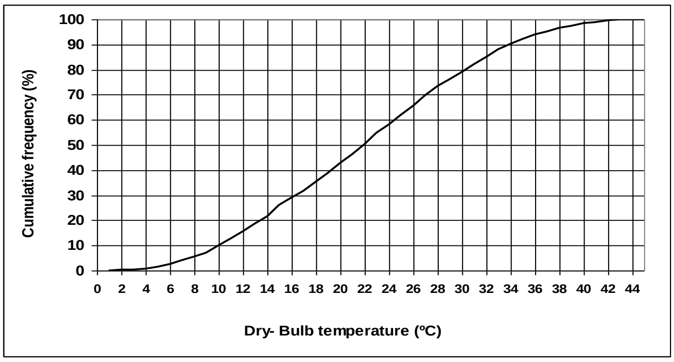

Fig. 7. Cumulative frequency distribution of DBT

Figs. 8 and 9 show frequency of occurrence and related repeating times of each DBT during the entire year. The minimum 1°C and maximum 45°C DBT are repeated only one time and two times, in 365-day, respectively. Year-round maximum and minimum repeated DBT were 23.5°C and 1°C respectively, whereas in summer 40°C and in winter 5-6°C outdoor design DBT are both repeated exactly 27 times corresponded to 99% and 1% of frequency level.

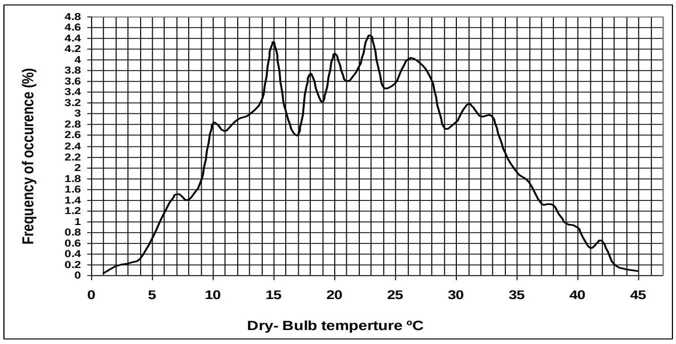

Fig. 8. Frequency of occurrence for DBT

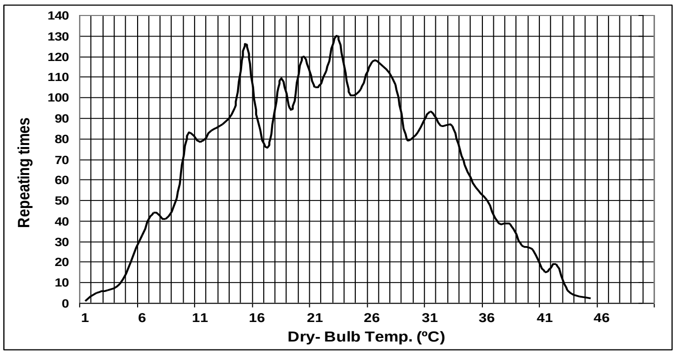

Fig. 9. DBT repeating times in one year

4. Conclusions

Weather data for Waddan city in Libya measured at three-hrs interval daily for the year 2007, were gathered and analyzed by using Microsoft Excel software. Statistical and graphical methods were used to study weather characteristics. Two common climatic variables, namely Dry Bulb Temperature (DBT) and Relative Humidity (RH) were investigated. It can be revealed that temperature is the key weather parameter. Incorrect selection of outdoor design temperatures can be costly when system and plant operations are considered. If extreme weather conditions are taken, uneconomical design and over sizing may result. On the other hand, if a climatic factor influential to the system has not been considered properly, the plant may not be able to cope with actual operation conditions, especially during peak loads. Based on the above detailed weather data analysis, the dry bulb temperature range of 22-40°C (where 22°C is the minimum indoor design temperature and 40°C is maximum outdoor design temperature) and the relative humidity (RH) of 44% (an average value) are considered to be the optimum design parameters. It has also been observed, from the analysis of relative humidity curves, that during the day, the weather conditions of humid-arid zones were completely different from the conditions at night. Very humid and warm during the day and low-to-moderate humid and cold during night for the entire year.

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