Determination of Outdoor Design Temperatures and Relative Humidity for Different Cites in Libya

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***Abstract*— The importance of choosing external climatic parameters such as temperature and relative humidity, which naturally determine the energy consumption of such variables, is of paramount importance, especially if the measurement difference between indoor and outdoor conditions is extreme. Therefore, this study attempts to choose a more accurate design temperature and relative humidity for several Libyan cities based on climatic data over 30 years (1990–2020). By using the data of fifteen different meteorological observation stations, distributed over several climatic regions (the Mediterranean coast in the north and the desert in the south) in this study, By calculating the monthly average temperature and relative humidity over the mentioned years, hence, a code was constructed by MATLAB capable of calculating the monthly average as well as choosing the design temperatures through data analysis, statistically based on the methodology and provisions set by ASHRAE for several Libyan cities for the first time (15 cities) and thus filling a large knowledge gap in the literature, especially calculations of energy consumed in buildings, as well as it was noted that the meteorological data that were analyzed during only two years in a previous study yielded results with a level of accuracy comparable to that of thirty years. Accordingly, it is therefore concluded that the data obtained over two years represents the minimum for any similar future endeavors.**

Keywords— **Design temperatures; Relative Humidity; Outdoor Conditions; Accumulative Frequency; HVAC System.**

I. INTRODUCTION

Outdoor design conditions, as easily measured weather metrics, provide designers with characteristic climatic features of a particular geographic location. Commonly measured data include solar radiation, wind speeds, air temperature, humidity, and precipitation levels. These metrics collectively form the basis for both the sizing/ scaling of HVAC systems and energy requirement estimation for buildings. Given the natural variability of outdoor design conditions, however, designers have often found it difficult to determine a single-valued design parameter to build their calculations upon. The conventional approach in the design of HVAC systems, for example, involves the estimation of peak design loads at specific hours of a single day with indoor and outdoor temperatures. While outdoor design weather data, used in the estimation of building energy requirements, represents the severe /prevalent climatic conditions in a given location. The collection of outdoor temperatures typically involves several meteorological stations experimentally measuring temperatures in a time-based fashion. Statistical methods are subsequently employed on the long-term weather data collected to extract mean temperatures usually reported monthly [1,2]. Other supporting design data may be included depending on the situation. The types and quality of data required for the design conditions may range from a very simple set of design temperatures to detailed descriptions of the local weather conditions. Therefore, this study had to provide data and calculate the outdoor design conditions for 15 cities in Libya distributed North and South to cover most of the Libyan regions.

A. Typically Chosen Outdoor Design Conditions

First before any practical undertaking concerning the thermal design estimation of buildings is carried out, the different methods and design data required are first ascertained. The typical design parameters necessary for the design of HVAC systems are listed and briefly described below:

- Latitude, Longitude, and elevation information (geographic information)
- Outdoor dry-bulb (DBT) and wet-bulb (WBT) temperatures
- Wind pattern data (prevailing direction and intensity)
- Prevailing humidity or moisture content in the specified geographic region

- Solar irradiance data with cloud shading probability
- Information regarding the seasonal variation of climate (temperatures, humidity, etc.) on both a daily and yearly basis
- Miscellaneous data on rainfall (precipitation rates) and extreme temperature fluctuations

Current methods for determining outdoor design temperatures are similar in basic principles.

B. Research Motivation

Due to the importance of external parameters such as temperature and value of relative humidity and the impact of these parameters on the appropriate thermal design of a building, which includes all structural elements attached to the environment, which results in an increase or decrease in demand for electrical energy, the absence of a specific design temperature as well as a particular value of relative humidity the designer depends on it in designing buildings for multiple regions in Libya, resulting in a random design that is not based on accurate numbers, resulting in an increase in electrical loads and making the state unable to provide the increased demand, and for these reasons, this study was chosen, which will determine the design temperatures as well as a specific value for the relative humidity of 15 cities distributed over different geographical areas, which may contribute to the selection of building materials, which may contribute to reducing the cooling or heating load , as well as having a database that contributes to the selection of thermal as well as solar systems.

II. Methodology

A. Data collection

Weather data of maximum and minimum temperatures, as well as relative humidity for a period of 30 years from 1990-2020, were obtained from the climatic department in Libyan Meteorology National center LMNC and the World Climate data site. It is a database of global weather and climate data with high spatial resolution.

B. The method used in the study

In this study, the method was chosen, (ASHRAE standard), which the American Society of Heating Refrigerating and Air-Conditioning Engineers, this method is most widely accepted in the HVAC industry. Design temperatures for the summer frequencies of 1%, 2.5%, and 5%, and the winter frequencies of 99% and 97.5% are provided, every hour in a day or at least two reading for maximum and minimum temperature [3]. The other design data provided includes the mean daily range of temperatures, mean annual extreme of DBT, wind speed, and direction. Design data could be obtained from ASHRAE method for locations in the United States, Canada, and some chosen locations in the world (Including Tripoli and Benghazi in Libya) could be obtained from in [1,4]. For nominating the required design temperatures, four months; June, July, August, and September with a total of (2928) hours are chosen as the summer period in the Northern hemisphere while December till March with a total of (2904) hours are chosen in the Southern hemisphere. Following the same method of choosing the related periods, the months of December, January, and February with a total of (2160) hours are nominated as the winter period in the Northern hemisphere while June, July, and August with a total of (2208) hours are selected in the Southern hemisphere. Taking energy conservation into consideration, ASHRAE Standard 90A 1980 advised that values from important levels of 97.5% values for winter and 2.5% for summer must be taken into the analysis. The latest [5]. however, mentioned that in the summer, the cooling design temperatures shall not exceed the design DBT listed in the 2.5% column or statistically related to the 0.5% yearly value. For the winter period, the heating design temperature shall be no lower than the design DBT listed in the 99% column or statistically similar to the 0.2% annualized value. This study presented, given that the available data is the maximum and lowest reading per day for thirty years, which is equivalent to (21600) readings, in which all the points based on the mentioned method were applied to find the design temperature as well as humidity.

Because the data was obtained for 30 years and therefore considered a difficult task in the calculation process, and therefore to facilitate this, A code was created using MATLAB that calculates the monthly average temperature, in addition to choosing the design temperature and relative humidity for each city based on the input data for each city for temperature and relative humidity for 30 years, as well as following the steps and criteria mentioned in the method used

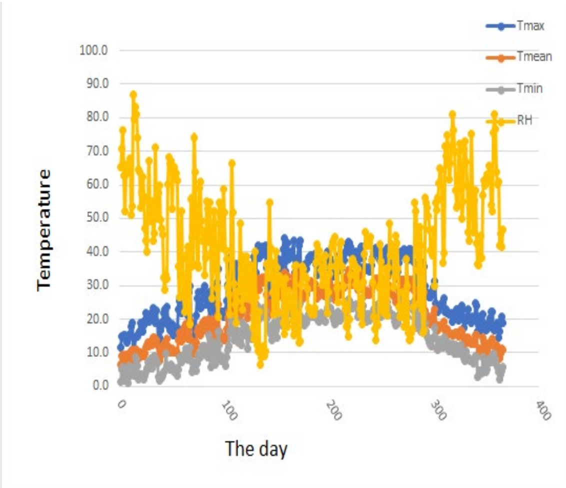

Figure (1). Dry-bulb temperature distributions in (2020) (720) readings (2 readings/day) in Hon

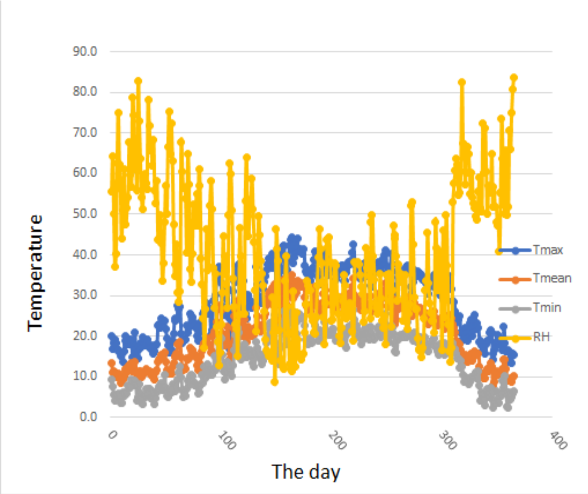

Figure (2). Dry-bulb temperature distributions in 1990 (720) readings (2 readings/day) in Hon

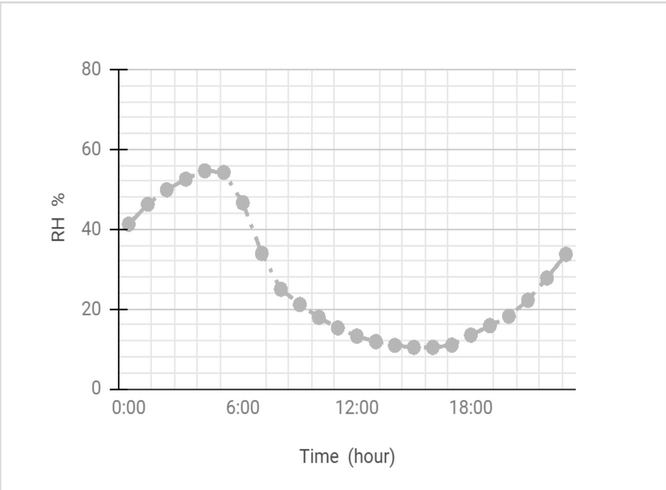

Figure (3). Relative humidity distributions in Hon in 1-8-2020

C. *Previous Work*

Headings A previous study [6] was conducted on an oasis in the northeast of the Fezzan region in southwest Libya (Wadan city). The dry bulb temperature (DBT) and relative humidity (RH) were collected for the full year of 2007, presented, and graphically analyzed from weather observed stations located in the Sahara Desert. This study concluded that the range of Dry bulb temperature of 22°C to 40 °C and relative humidity of 44% has been suggested as the external design criteria to be considered during design or selection. It was also observed from the analysis of relative humidity curves that daytime weather conditions in humid arid regions were quite different. about night conditions. Very humid and warm during the day and low to moderately humid and cool at night all year round. The presented study is considered complementary to this study as it will cover the area of most of the Libyan regions

III. RESULTS AND DISCUSSION

A. *Prevailing DB Temperature and Relative Humidity*

The Prevailing Dry Bulb Temperature (DBT) and Relative Humidity (RH) for 30 years (1990-2020) (21600) readings in 30 years; by 2 readings rates, as maximum and minimum readings per day for each city) were collected and graphically analyzed using MATLAB software. The data were available for thirty years (1990-2020) from 15 weather observation stations distributed in the north and south regions of Libya. These locations are meteorologically classified as Arid, semi, and non-arid sites. Hon is a Saharan desert oasis in the North-East of Fezzan region of South-West Libya. It is in Al- Jufrah area. It is located 285 km south of the Libyan North Coast. Its coordinates are 29.1139 Nº 15.9355 Eº. Fig. (1) shows (720) readings of distributed DBT and RH data points in 1990-2020 Figs. (1 and 2) were the readings for the highest and lowest dry bulb, temperatures are 46 C° and 1 C° respectively in 2020 the highest and lowest dry bulb, temperatures are 44 C° and 1 C° from the aspect of energy consumption, these numbers require a large amount of energy to reach the temperatures to the comfortable rate. As for the relative humidity, the city of Hon has an arid climate. It has been found the humidity in the summer is almost non-existent during the day and the maximum of what reaches it at night is about 60% as shown in Fig (3). The monthly maximum means dry-bulb temperature and monthly minimum mean dry-bulb temperature are graphically presented in Fig (4). shows a graphical comparison between monthly mean maximum and minimum dry-bulb temperatures. It was found that the highest monthly mean of the maximum temperatures is in the summer months - Jun - Jul - Aug and the lowest monthly mean of the lowest temperatures is Dec - Jan - Feb the range of temperature difference is nearly the same between monthly maximum mean DBT in the summertime and mean minimum DBT in winter times. The range was very close to 12 and 15. Dry-bulb temperature values are also presented in Fig. (5) to compare between daily mean DBT in August (the hottest month) and daily mean DBT in January (the coldest month). It is natural that the area between the two curves in Fig (5) will impact comfort levels, whether in the summer or winter when choosing materials that do not insulate the outside to the inside. therefore, the importance of having a design value for temperatures is very important.

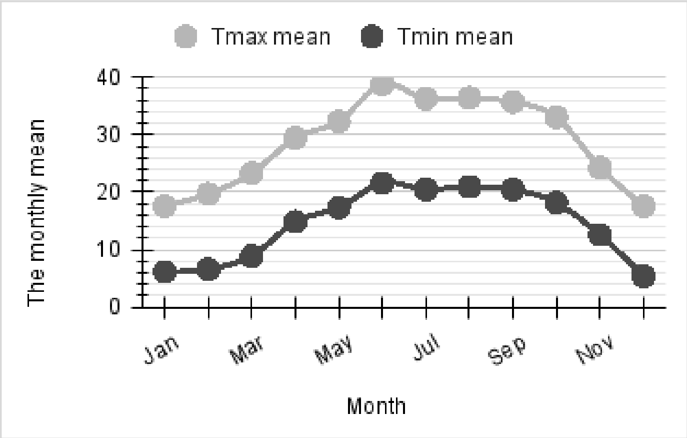

Figure (4). Monthly maximum mean and minimum mean DBT in 2020

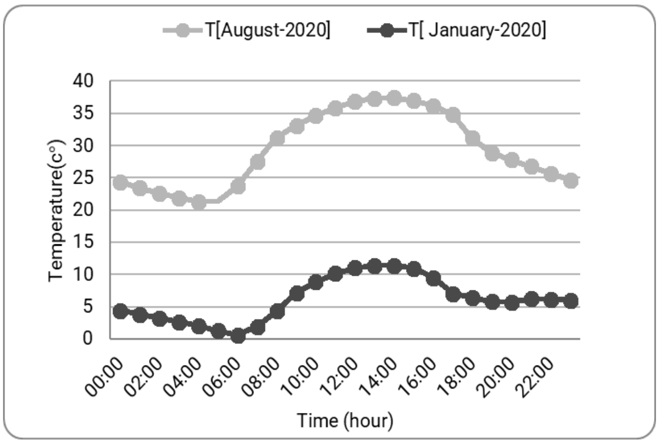

Figure (5). Mean DBT distribution in January and August 2020

B. *Outdoor Design Temperature*

Outdoor design temperatures, commonly utilized in thermal load estimations, refer to the maximum/worst case-scenario temperatures in a particular geographic location that are used to calculate the average thermal requirements necessary for a particular building. [1] The ASHRAE design standard recommends utilizing a total of five cumulative frequency levels (0.4%, 1.0% 99%, and 99.6%,97%) to estimate average outdoor design temperatures. These percentile frequency levels refer to the percentage of a year in which a temperature exceeds a standard level (ASHRAE 1989). The selection of frequency levels and the subsequent outdoor design temperatures are paramount and are ultimately based on the local design codes and considerations commonly practiced in a region. One of the main purposes of an HVAC system is to provide an adequate thermal comfort level for the occupants of a building. However, in the design conditions of thermal systems, the common practical way is to nominate the outdoor design conditions at 1% and 99% of frequency levels for summer cooling and heating load design analysis respectively. As shown, clearly from the accumulative frequency curve in Fig (6) the summer and winter outdoor dry-bulb design temperatures in the period from (1990- 2020) are found to be 42 C° and 2-3 C° corresponding to 99% and 1% respectively of cumulative frequency levels, as guided by ASHRAE handbook. Fig (7) shows the frequency of occurrence of temperatures in the past thirty years, during the period (1990-2020). The lowest temperature and the maximum temperature in Hun in 30 years were 1C° and 46 C°, but from this figure, it is clear that it is the least frequent in the thirty years with several recurrences that do not exceed The two times in this figure, it has observed a curve with three peaks, the two smallest peaks were at 7C° with a frequency of more than 295 times, and the other smallest at 36 C° with a frequency of more than 330 times, and the largest peak is at 21C˒ with a recurrence of more than 600 times, it has been observed cumulative rate of decrease per temperature for the low temperatures was offset by the rise in the cumulative rate per temperature for the moderate temperatures.

C. *Outdoor Design Relative humidity*

Relative Humidity is defined as the ratio between the measured absolute humidity vs. the maximum possible absolute humidity in a given environment. Therefore, a reading of 100% Relative Humidity signifies that the air is no longer capable of holding any further moisture and the probability of condensation/precipitation is high. It, therefore, follows that the value of Relative Humidity in controlled environments plays a crucial role in the overall thermal comfort of its occupants since the human body relies on the mechanism of sweating and subsequent evaporation to cool down body. A high value of Relative Humidity inhibits this natural mechanism by the air's inability to hold any further moisture content from the body, hence giving the illusion of higher temperatures when in fact non-existent. The opposite is true, however, when lower values of Relative Humidity are prevalent, the body easily cools down via evaporative cooling. Maintaining proper levels of Relative Humidity in building environments is ergo of paramount importance in the quest to achieve thermal comfort for the occupants. In this study, the same method used in choosing the design temperature in winter and summer for Hon city was used, which is by using the ASHRAE method for all remaining cities.

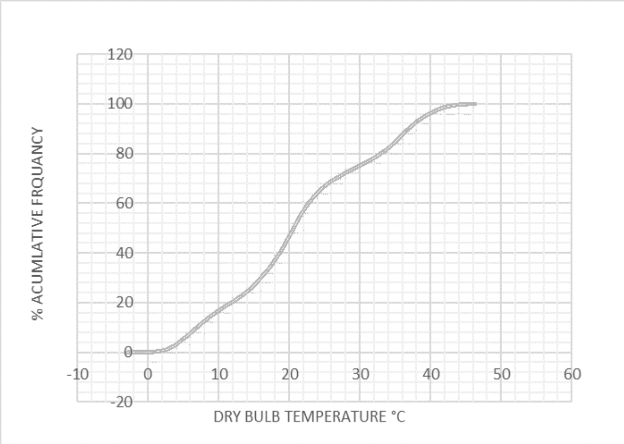

Figure (6) Accumulative frequency distribution of DBT for Hon

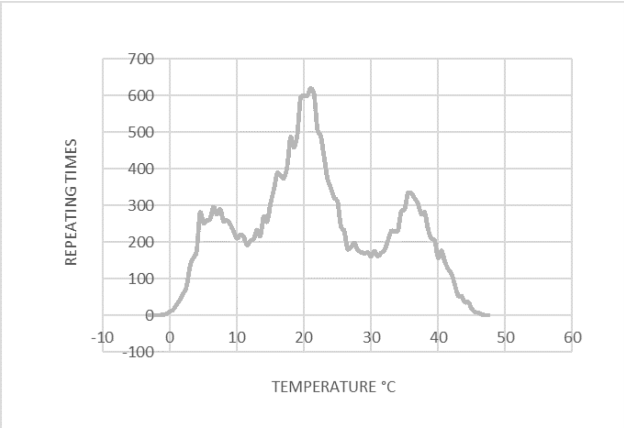

Figure (7). DBT repeating times in thirty years in Hon in period (1990-2020)

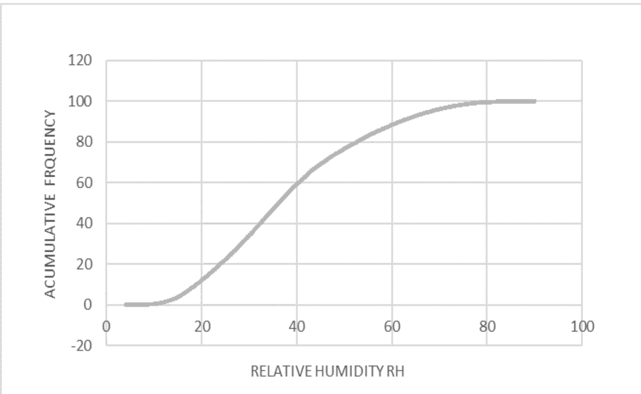

Figure (8) a cumulative frequency for RH% in Hon in thirty years in period (1990-2020)

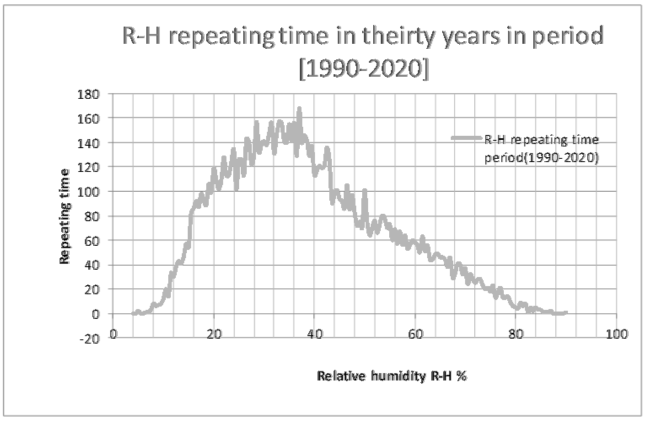

Figure (9). Relative humidity repeating times in thirty years in Hon in period (1990-2020)

Thus, choosing the design values of relative humidity in the summer frequencies of 1%, 2.5%, and 5%, and the winter frequencies of 99% and 97.5% are provided, from the providing data in thermal design conditions the usual practice is to determine outdoor design conditions at 1% and 99% frequency levels for summer cooling and heating load, analysis respectively as shown clearly from the accumulative frequency curve in Fig(8) the summer and winter design relative humidity in the period from (1990-2020) in hon city is found to be 70% and 5-6% corresponded to 99% and 1% respectively of accumulative frequency levels as guided by ASHRAE handbook Fig. (9) shows the recurrence of relative humidity values for 30 years it was observed in Fig. (8) that the lowest and highest values which are 5-6% and 70% were not repeated in Fig(9) except 3 and 24 times respectively the most frequent value which is 37% was repeated 168 times.

It was observed that the relative humidity in the winter and summer seasons reaches rates of more than 60%, and therefore there is difficulty in choosing a single design value for summer and winter, and therefore the humidity values were by counting the months of January and August, as the coldest, hottest month for period 30 years, by using the MATLAB program. and the method used to find the design values of relative humidity, so that there are two design values for relative humidity for the winter and summer seasons as shown in figs (10, 11). Thus, the value of the relative humidity in the winter season at 99% equals 77% and the value of 1% equals 14% and the most frequent value is 66%. as In figures (12,13) the value of relative humidity at 99% is 47%, but at 1% is 10%, and the most frequent value is 36%. This study was conducted on 14 locations in the same way that was used to find the design conditions for the city of Hun. It was summarized in a table that includes the design temperatures for winter and summer and the relative humidity values for each city as shown in table (1)

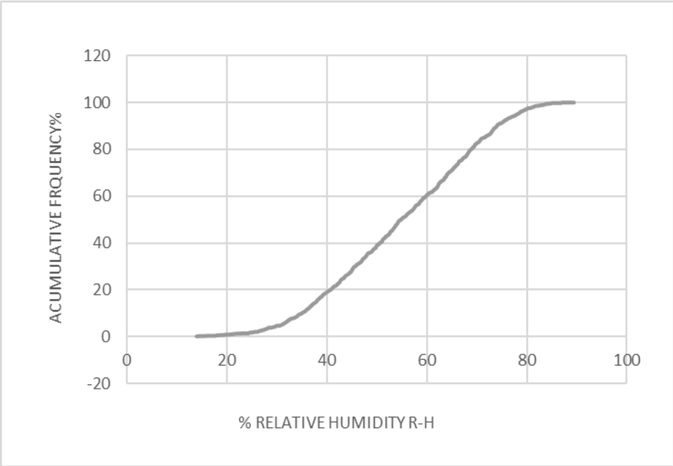

Figure. (10). A cumulative frequency in winter from (1990-2020) in Hon

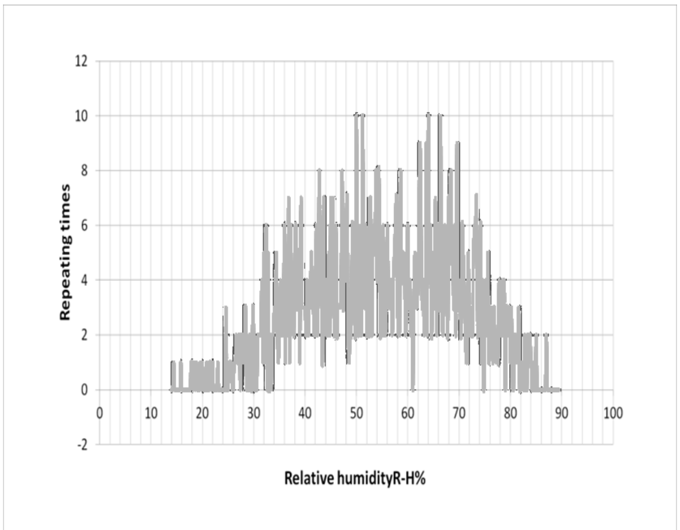

Figure. (11). Repeating time in winter from (1990-2020) in Hon

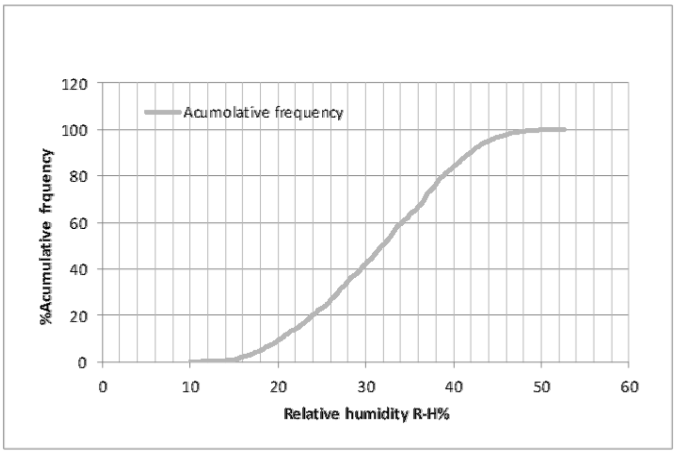

Figure (12). Accumulative frequency in summer from (1990-2020) in Hon

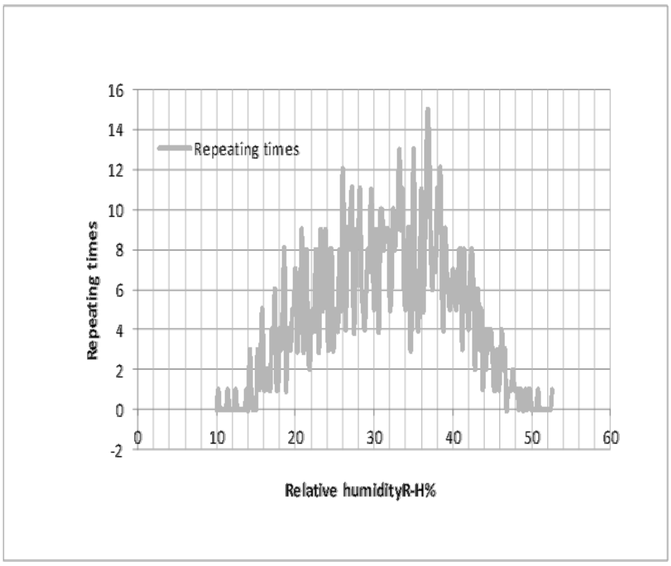

Figure (13). repeating time in summer from (1990- 2020) in Hon

IV. CONCLUSIONS

In this study, the prevailing weather data in Libya were obtained from the temperature and relative humidity for the period (1990-2020) through 15 weather observation stations distributed over the north and south regions. Using the MATLAB program had made a code that calculates the monthly mean of dry bulb temperatures and relative humidity for 30 years. As well as calculating the design temperature for Summer and winter for each region. the basis observations for the present study

1. The cumulative curve of temperatures for 30 years for the city of Hon. It was observed that the increase in moderate temperatures is constantly increasing for 30 years and thus gives an indication that the minimum temperatures have decreased and the moderate degrees have risen, and this gives another, indication that the minimum temperatures are heading for moderation and that the temperature of the planet is heading to rise.

2. It is observed through a comparison between the previous study of the city of Waddan and the present study of the design temperatures for the winter and summer seasons for the location of the city of Hon, which is about 40 km away from Waddan. The design values are not far away, and

therefore, it can be said that a year or two is sufficient to obtain the design values for temperature and humidity for any place.

3. It was also observed that the relative humidity in the city of Hun does not exceed 77% in the winter and is as low as possible in the summer at 5%. This is due to the amount of heat reflected from the sand during the day. And it increases at night, unlike coastal places, for example, Benghazi, where the humidity in the winter reaches about 86% and is not less than 20 % in the summer, due to its near to the sea, where the air is saturated with seawater.

4. It was also observed that the relative humidity in the winter and summer seasons reaches rates of more than 60%, and therefore there is difficulty in choosing a single design value for summer and winter, and therefore the humidity values were by counting the months of January and August, as the coldest, hottest month for period 30 years, by using the MATLAB program. The method used to find the design values of relative humidity, so that there are two design values for relative humidity for the winter and summer seasons.

5. . Derna is geographically located between a sea and a mountain. stream of the airflow rushing from the sea and use the mountain force it to rise to the up. This air has high humidity and therefore its density is high. Where it will return to the earth, and this is the reason why the temperature in the summer reaches 32 c°

6. High humidity in winter may be due to the rise of hot air stream flow to the up, where they are saturated with water vapor from the clouds, their density increases, and they head to the ground again loaded with high humidity or rain. The other reason is that temperatures in the winter may reach temperatures higher than 20 c°, the passage of air in contact with water surfaces and the low pressure at that time helps it evaporate, thus the humidity of the air will increase. These reasons could be what made the humidity reach 86% in Benghazi.

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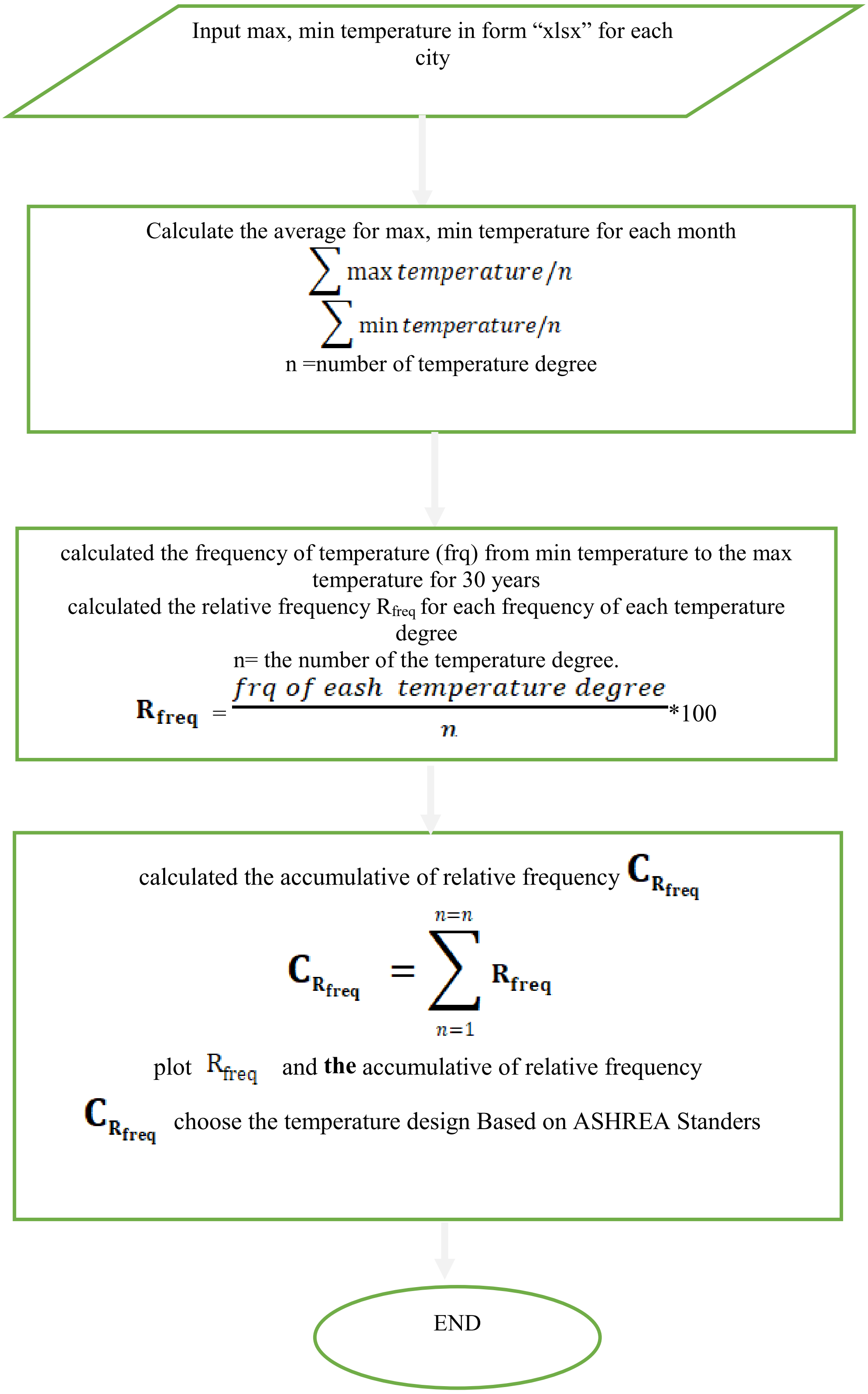
Table 1. Design temperatures and relative humidity values for 15 cities in Libya

Design summer and Winter temperatures and Relative Humidity for 15 Libyan Cities								
Relative Humidity								
City	**Tw(c°)**	**Ts(c°)**	**winter**			**summer**		
			RH_{max} %	RH_{frq} %	RH_{min} %	RH_{max}%	RH_{frq} %	$\boldsymbol{RH_{min}}$ %
Ajdabiya	6	38	83	71	39	70	56	19
Alkofra	2	42	70	57	11	30	28	5
Benghazi	7	36	86	75	46	76	67	20
Derna	6	32	83	77	48	77	70	20
Ghadames	0	44	83	55	18	42	20	2
Hun	3	42	77	66	14	47	36	5
Jalo	5	41	75	70	20	46	31	7
Misrata	7-8	36	83	69	44	74	65	20
Nalot	1	43	80	61	23	37	27	7
Sabha	0	43	70	37	13	32	17	5
Surt	8	36	82	70	39	75	67	25
Shahat	5	31	86	78	46	73	67	25
Tobruk	7-8	34	84	70	46	80	72	32
Tripoli	6	40	83	71	40	71	55	20
Ezwara	5	39	81	67	37	70	60	18

Appendix


Input max, min temperature in form “xlsx” for each city
Calculate the average for max, min temperature for each month
$\sum \max temperature/n$
$\sum \min temperature/n$
n =number of temperature degree
calculated the frequency of temperature (frq) from min temperature to the max temperature for 30 years
calculated the relative frequency R_{freq} for each frequency of each temperature degree
n= the number of the temperature degree.
$R_{freq} = \frac{frq\ of\ eash\ temperature\ degree}{n} * 100$
calculated the accumulative of relative frequency $C_{R_{freq}}$
$C_{R_{freq}} = \sum_{n=1}^{n=n} R_{freq}$
plot R_{freq} and the accumulative of relative frequency
$C_{R_{freq}}$ choose the temperature design Based on ASHREA Standers
END