Development of Standard Weather Data Correlation of Seoul

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ABSTRACT: Standard temperature and absolute humidity weather data correlations of Seoul for dynamic energy simulation have been developed regressing the measured data compiled by the Korea Meteorological Adminstration during a 10-year period from 1991 to 2000. The mathematical equations can generate consistent daily and yearly variations of outdoor weather data unlike the measured data which may show abnormal behavior. Considering that each hour of the day follows a certain yearly pattern, 24 correlations are developed for each hour of the day. The derived simple mathematical equations can be used for estimating outdoor temperature and humidity conditions for any arbitrary time of the year.

Nomenclature

AH	: absolute humidity [g/kg$_{da}$]
A_n, B_n	: coefficient of Fourier series
T	: outdoor temperature [℃]
x	: day

1. Introduction

The first step in the design of air-conditioning systems is the calculation of heating and cooling loads of the building that depend on its building geometry and materials, the indoor conditions to be maintained, and most importantly on the outdoor weather conditions. If the air-conditioning system is expected to provide comfortable indoor conditions at all times, it should be designed for peak conditions that are determined by the most extreme weather data recorded.(1)

Predicting the performance of a solar system by using simulation methods requires weather data input of the location where the system is installed.(2) Computer simulation of building and plants is used increasingly in energy assessments and design, and this generally requires hourly weather data. Data for outdoor design conditions are usually determined by statistical analyses of long term meteorological records collected from local weather stations.

Weather is one of the primary determinants of indoor thermal conditions and energy use for space conditioning. The climate of a particular location influences building designs and dictates the methods of HVAC control. The long-term data set is recommended to be at least 10 years long. In particular, dynamic simulations using modern computer programs such as DOE-2 or HASP require hourly data of weather conditions of solar radiation, dry-bulb temperature, dew point temperature or humidity, atmospheric pressure, wind direction, and wind speed. Since weather conditions can vary significantly from year to year, researchers in many countries have devised typical meteorological year (TMY) data to represent long-term typical weather conditions. For computer simu-

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lation, the weather data must have hourly records of at least temperature, humidity, wind speed, and both direct and total solar radiation. Furthermore, to avoid random variations of weather from year to year, the standard weather data should be for a hypothetical typical year, rather than the actual data which may show some inconsistencies.(3)

With simulation becoming an important part of the design process of plants and building, there is an increasing need for hourly standard weather data. In Korea, the standard weather data has been studied from 1980's, but no work has been done to present the standard weather data with simple mathematical correlations.

In this paper, standard weather data correlation of Seoul for dynamic energy simulation has been developed regressing the measured data compiled by the Korea Meteorological Adminstration (KMA) during a 10-year period from 1991 to 2000. The standard weather data consists of 8760 values of various selected meteorological parameters which are ambient temperature, solar radiation, relative humidity and wind velocity.

This paper proposes a new procedure for determining a set of typical weather data in order to evaluate the long-term performance of buildings. This set consists of two meteorological parameters: ambient temperature and absolute humidity. Considering that each hour of the day follows a certain yearly pattern, the correlations are developed for each 24 hour of the day. The derived 24 simple mathematical equations can be used for estimating outdoor temperature and absolute humidity conditions for any arbitrary time of the year. The mathematical equations can generate the daily and yearly variations of outdoor condition with consistency unlike the measured data which may show abnormal behavior. The new selection process is quite straightforward, easily applicable and can be reliably applied in predicting the long-term energy related performance of buildings, minimizing the error in the estimation.

2. The present state of standard weather data in Korea

To determine the standard weather data, compilation of measured weather data is necessary. Since 1904, KMA has measured weather condition in Busan, Incheon, Mogpo. Now, there are 543 weather stations in operation. Since these weather stations are located in 460 different provinces of Korea, they cover almost all parts of the country.

The weather design data being used in load calculations and energy analysis are a main factor that determines accuracy of the results. Design data are usually determined by statistical analyses of long-term weather observations. The observations should cover a long period of time and should include recent data.

Examples of well known standard weather data are Typical Meteorological Year (TMY), Weather Year for Energy Calculations (WYEC) and Test Reference Year (TRY). The typical weather data (TWD) consists of 8760 values of various selected meteorological parameters such as ambient temperature, solar radiation, relative humidity and wind velocity are originally derived from long-term data.(2)

The number of years for which the weather data are available determines the breadth of the weather database. In principle, as many years as possible should be considered for proper analysis. The longer the period of the record is, the better the results will be (since short period may exhibit abnormal variations). Ten or more years of weather data are required to increase the statistical reliability of the models for weather data prediction and thus for the estimation of cooling and heating loads.

Table 1 shows the standard weather data for HASP/ACLD input data. These files will provide

Table 1 Standard weather data of Korea for HASP[4]

Researcher	Year	Region	Period
D. C. Kim (KMAC)[1]	1984	Seoul	1971~1980
J. Y. Shon (HU)[2]	1985	Seoul	1971~1980
M. K. Cho (DNUT)[3]	1986	Seoul, Incheon, Suwon, Mogpo, Gangneung, Jeju, Gwangju	1974~1983 (Seoul : 1973~1982)
H. K. Kim (SNU)[4]	1987	Seoul, Cheongju, Mogpo, Jinju, Gangneung, Gwangju	1974~1983
D. C. Kim (Hanil MEC)	1991	Seoul, Busan, Daegu, Gwangju	1982~1989
	1992	Jeonju, Daejeon, Gangneung, Jeju	1982~1991 (Daejeon : 1984~1991)

1. KMAC : Korea Military Academy
2. HU : Hanyang University
3. DNUT : Daejeon National University of Technology
4. SNU : Seoul National University

architects and engineers with typical weather conditions of temperature, humidity, wind direction and velocity, and solar radiation for all major cities in Korea, which can be conveniently used in building energy simulation programs.

3. The development of standard weather data in Seoul

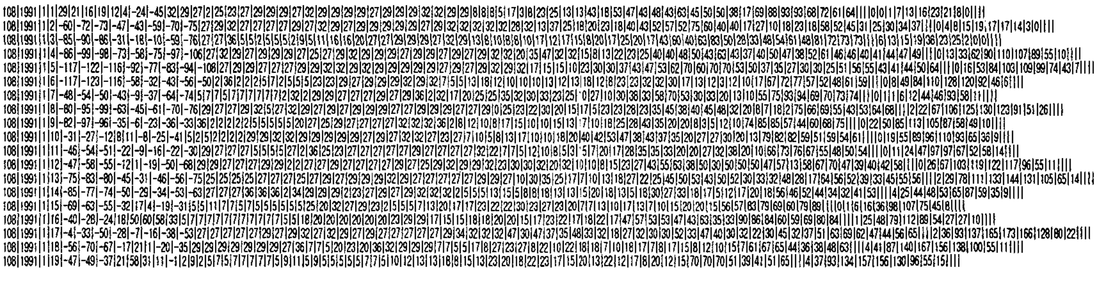
Weather data of Seoul has been collected and published by KMA. The meteorological parameters collected are: ambient temperature, relative humidity, global radiation on horizontal surface, wind direction and wind velocity.

Table 2 shows the original data format of KMA. Figure 1 provides original weather data form of KMA. The ambient temperature and relative humidity are at three-hour interval.

The solar radiation is measured from sunrise to sunset every 1 minute and the result is in-

Table 2 Data format

Note				Temperature (℃)								Humidity (%)		
location	year	month	day	03	06	09	12	15	18	21	24	03	06	09
Humidity (%)					Solar radiation (0.01 MJ/m²)									
12	15	18	21	24	05	06	07	08	09	10	11	12	13	14
Solar radiation (0.01 MJ/m²)						Wind speed (0.1 m/s)								
15	16	17	18	19	20	01	02	03	04	05	06	07	08	09
Wind speed (0.1 m/s)														
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24



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108|1991|1|1|29|21|16|19|12|4|-24|-45|32|29|27|2|25|23|27|29|29|29|27|32|29|29|29|29|27|29|29|29|32|32|29|29|8|8|8|5|17|3|8|23|25|13|13|43|18|53|47|43|48|43|63|45|50|50|38|17|69|88|93|93|68|72|61|64|||0|0|1|7|13|16|23|21|8|0|||
108|1991|1|2|-60|-72|-73|-47|-43|-59|-70|-75|27|29|32|27|27|27|27|29|27|32|29|27|29|29|29|29|29|27|29|32|32|32|32|32|28|32|13|37|25|18|20|23|18|40|43|52|57|52|75|60|40|40|17|27|10|18|23|18|58|52|45|31|25|30|34|37|||0|4|8|15|19|17|17|14|3|0|||
108|1991|1|3|-85|-90|-86|-31|-18|-10|-59|-76|27|27|36|5|5|2|5|5|5|2|9|5|11|16|16|20|27|27|29|29|29|27|32|29|13|8|10|8|8|10|17|12|17|15|8|20|17|25|20|17|43|60|40|63|83|50|28|33|48|54|61|48|81|72|73|73|||6|13|15|19|36|23|25|2|0|0|||
108|1991|1|4|-86|-99|-98|-73|-58|-75|-97|-106|27|32|29|27|29|29|29|27|25|27|29|32|29|29|29|27|29|29|27|29|27|29|32|32|20|35|47|32|32|15|8|13|22|23|25|40|40|48|50|43|63|43|37|40|50|47|38|52|61|46|46|40|41|44|47|49|||0|13|33|62|90|110|107|89|55|10|||
108|1991|1|5|-117|-122|-116|-92|-77|-83|-94|-108|27|29|29|27|27|27|29|29|32|32|29|32|29|29|29|29|29|27|29|27|29|32|29|32|17|15|15|10|23|30|30|37|43|47|53|62|70|60|70|70|53|50|37|35|27|30|30|25|51|56|55|43|41|44|50|64|||0|16|53|84|103|109|99|74|43|7|||
108|1991|1|6|-117|-123|-116|-58|-32|-43|-56|-50|2|36|2|2|2|5|7|2|5|5|5|23|23|29|27|29|29|29|32|29|32|7|5|5|13|18|12|10|10|10|13|12|13|18|12|8|23|23|32|32|30|17|13|12|3|12|10|17|67|72|77|57|52|48|61|59|||0|8|49|84|110|128|120|92|46|6|||
108|1991|1|7|-48|-54|-50|-43|-9|-37|-64|-74|5|7|7|5|7|7|7|7|7|7|2|32|2|29|29|27|27|27|29|27|29|36|2|32|17|20|25|25|35|32|30|33|23|25|0|27|10|30|38|33|58|70|53|30|33|20|13|10|55|75|93|94|69|70|73|74|||0|1|1|6|12|44|46|93|58|11||||
108|1991|1|8|-80|-95|-99|-63|-45|-61|-70|-76|29|27|27|29|32|5|27|32|29|27|29|27|29|29|29|27|27|29|29|29|27|27|29|0|25|23|22|30|20|15|17|5|23|23|28|23|35|45|38|40|45|48|32|20|8|7|18|2|75|66|69|55|43|53|64|68|||2|22|67|106|125|130|123|91|51|26||||
108|1991|1|9|-82|-97|-96|-35|-6|-23|-36|-33|36|2|2|2|2|2|5|5|5|5|5|20|27|25|29|27|27|27|27|32|32|32|36|2|8|12|10|8|17|15|10|10|15|13|7|10|18|25|28|43|35|20|20|8|3|5|12|10|74|85|85|57|44|60|68|75|||0|22|50|85|113|105|87|58|49|10||||
108|1991|1|10|-31|-27|-12|8|11|-8|-25|-41|5|2|5|2|2|2|2|29|29|32|32|29|29|29|29|29|27|29|27|32|32|27|23|27|7|10|5|8|13|17|10|10|18|20|40|42|53|47|38|43|37|35|20|27|27|30|20|13|79|82|82|59|51|59|54|61||||0|19|55|89|96|110|93|65|36|9|||
108|1991|1|11|-46|-54|-51|-22|-9|-16|-22|-30|29|27|27|27|5|5|5|5|27|2|36|25|23|27|27|27|27|27|29|27|27|27|27|32|22|7|7|5|12|10|8|5|3|5|7|20|17|28|35|35|33|20|20|27|32|38|20|10|66|73|76|67|55|48|50|54|||0|11|24|47|97|97|67|52|58|14||||
108|1991|1|12|-47|-58|-55|-12|1|-19|-50|-68|29|29|27|27|27|29|29|2|2|27|27|29|27|27|27|27|29|27|25|29|32|29|29|32|23|30|30|32|20|32|10|10|8|15|23|27|43|55|63|38|50|30|50|50|50|47|57|13|58|67|70|47|39|40|42|58|||0|26|67|103|119|122|117|96|55|11||||
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108|1991|1|15|-69|-63|-55|-32|17|4|-19|-31|5|5|11|7|7|5|7|5|5|5|5|5|5|25|20|32|27|29|23|2|5|5|5|7|13|20|17|17|23|22|22|30|23|27|23|20|7|7|13|10|17|13|7|10|15|20|20|15|56|57|83|79|69|60|79|89|||0|1|6|16|36|98|107|75|45|8||||
108|1991|1|16|-40|-28|-24|18|50|60|58|33|5|7|7|7|7|7|7|7|7|7|7|7|5|5|18|20|20|20|20|20|20|23|29|29|17|15|15|18|18|20|20|15|17|23|22|17|18|22|17|47|57|53|53|47|43|63|35|33|90|86|84|60|59|69|80|84||||1|25|48|79|112|89|54|27|27|10||||
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108|1991|1|18|-56|-70|-67|-17|21|1|-20|-35|29|29|29|29|29|29|29|27|36|7|7|5|20|23|20|36|32|29|29|29|7|7|5|5|17|8|27|23|27|8|22|10|22|18|18|7|10|18|17|7|8|17|15|8|12|10|15|7|61|67|65|44|36|38|48|63|||4|41|87|140|167|156|138|100|55|11||||
108|1991|1|19|-47|-49|-37|21|58|31|11|-1|2|9|2|5|7|5|7|7|7|7|7|5|9|11|5|9|5|5|5|5|5|7|7|5|10|12|13|13|18|8|15|13|23|20|18|22|23|17|15|20|13|22|12|17|8|20|12|15|70|70|70|51|39|41|51|65|||4|37|93|134|157|156|130|96|55|15||||
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Fig. 1 Original weather data form.

Table 3 Weather data (Seoul)

Month	Day	Total time	Time of day	Day	Outdoor temperature [℃]	Absolute humidity [g/kg$_d$]	Solar radiation [J/m^{2}h]	Wind speed [m/s]
6	23	529	1	174	21.47	11.93	0	1.20
6	23	530	2	174	21.10	12.03	0	1.07
6	23	531	3	174	20.73	12.13	0	0.97
6	23	532	4	174	20.37	12.09	0	0.99
6	23	533	5	174	20.00	12.04	0	1.06
6	23	534	6	174	19.64	11.99	25	1.23
6	23	535	7	174	20.49	11.96	173	1.34
6	23	536	8	174	21.34	11.88	577	1.28
6	23	537	9	174	22.19	11.75	962	1.44
6	23	538	10	174	23.16	11.88	1366	1.73
6	23	539	11	174	24.13	11.97	1568	1.89
6	23	540	12	174	25.10	12.03	1760	2.09
6	23	541	13	174	25.04	12.05	1802	1.80
6	23	542	14	174	24.98	12.08	1398	2.62
6	23	543	15	174	24.92	12.10	1085	2.48
6	23	544	16	174	24.97	12.05	1253	3.05
6	23	545	17	174	25.02	12.00	892	3.31
6	23	546	18	174	25.07	11.95	580	3.01
6	23	547	19	174	24.13	12.00	264	2.82
6	23	548	20	174	23.20	12.02	32	2.50
6	23	549	21	174	22.26	11.99	0	2.45
6	23	550	22	174	21.82	11.99	0	1.72
6	23	551	23	174	21.38	11.98	0	1.61
6	23	552	24	174	20.94	11.96	0	1.52

tegrated for 1 hour. The wind velocity is measured every 1 minute and averaged for 10 minutes. Wind direction which is divided into 16 directions is measured every 1 minute.

In this study, standard weather data of Seoul were developed using measured data of KMA from year 1991 to 2000. The developed standard weather data of Seoul expresses hourly values of outdoor temperature, absolute humidity, solar radiation, and wind velocity from Jan. 1 to Dec. 31. The relative humidity is converted to absolute humidity since absolute humidity is more convenient for load calculations.

For use in thermal load simulations or annual energy calculations, the ambient temperature and humidity need to be expressed with one-hour interval. In order to produce hourly data from the three-hour interval data, the temperature and humidity are interpolated using cubic spline equation. This will produce a smoothened variation of outdoor weather. Table 3 shows standard weather data of Seoul on June 23 that has been generated using cubic spline equation.

4. The development of empirical equation of outdoor temperature and absolute humidity

In this study, empirical equation of outdoor temperature and absolute humidity has been developed using measured weather data of KMA from year 1991 to 2000. The weather data for energy simulation must be consistent with respect to time, but the measured data of KMA may lack this consistency, which may result in illogical results. Figures 2 and 3 show the variation of outdoor temperature and absolute humidity, respectively. The empirical equation for predicting outdoor temperature and absolute humidity is developed using Fourier series.

Irregular periodic functions occur frequently in engineering problems. Their representation in terms of simple periodic function, such as sine and cosine, leads to Fourier series.

This Fourier series is a convenient tool in presenting an irregular periodic function. Fourier series is, in a certain sense, more universal than Taylor series, because many discontinuous periodic functions of practical interest can be developed with Fourier series, unlike the Taylor series representations.

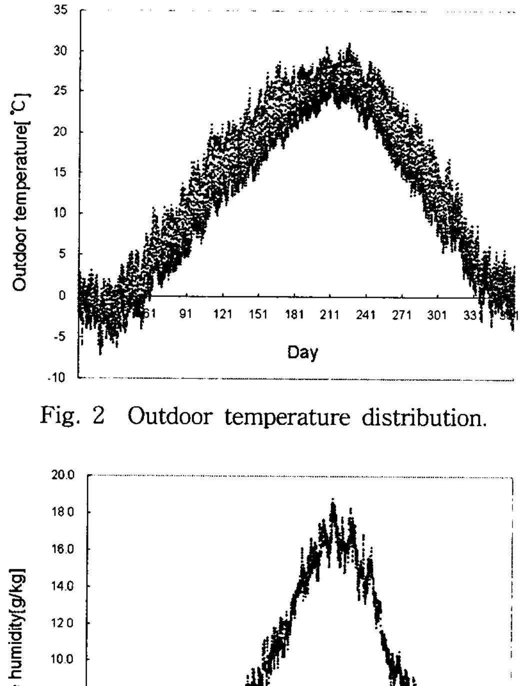

Fig. 2 Outdoor temperature distribution.

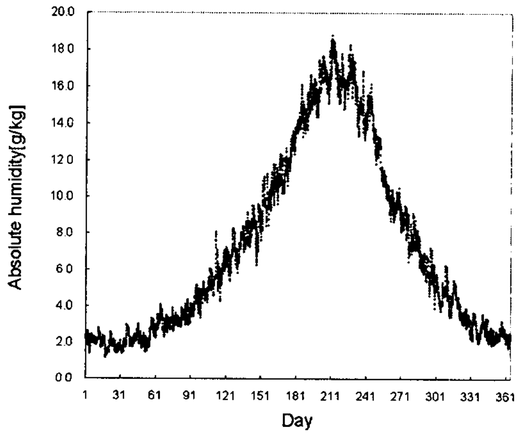

Fig. 3 Absolute humidity distribution.

4.1 Temperature correlation

Climatic conditions vary from one year to another. The dry bulb temperature determines the summer conduction heat gain, while solar radiation and wet bulb temperature are two parameters crucial to solar heat gain and latent load calculations, respectively. Figure 4 shows measured outdoor temperature on June 23, in 1991, 1993, 1995, respectively. In case of year 1991 and 1993, the outdoor temperature drops at 3 : 00 PM and ascends at 6 : 00 PM. This irregularity is quite abnormal and may cause misleading effect on thermal load calculation of buildings.

Temperature for each hour of the day is approximated by Fourier series as shown in Eqn. (1). Fourier series of order 3 is used for the temperature correlation. The coefficients A_n and B_n are determined by regressing the measured data and their values are given in Table 4.

$$T = A_0 + \sum_{n=1}^{3}\left(A_n \cos\frac{n\pi}{365}x + B_n \sin\frac{n\pi}{365}x\right) \quad (1)$$

Figure 5 shows the temperature variation of

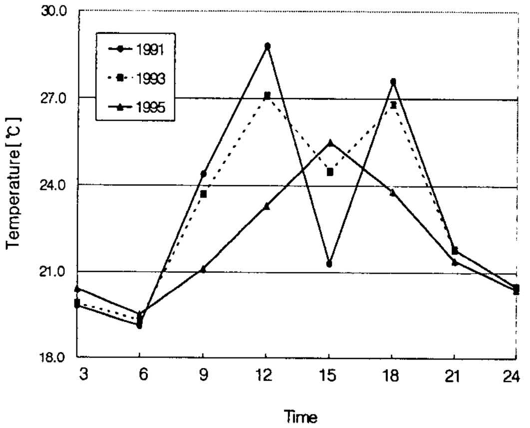

Fig. 4 Outdoor temperature variation (June 23).

Table 4 Coefficients for temperature equation

Time	A_o	Coe.	1	2	3
1	11.18781	A_n	−12.840610	−0.4296809	0.0603537
		B_n	−5.514139	0.1548266	−0.9266086
2	10.86745	A_n	−12.959580	−0.3627431	0.0762807
		B_n	−5.309174	0.2138016	−0.9615144
3	10.49507	A_n	−12.848790	−0.3465059	0.1085605
		B_n	−5.519800	0.2708277	−0.9811601
4	10.11225	A_n	−12.784280	−0.2839763	0.1308132
		B_n	−5.528726	0.3177598	−0.9878131
5	9.827178	A_n	−12.772410	−0.2467258	0.1422542
		B_n	−5.531077	0.3244540	−0.9806165
6	9.769589	A_n	−12.933630	−0.2792312	0.1313593
		B_n	−5.513370	0.2556720	−0.9561394
7	10.04345	A_n	−13.332030	−0.4094426	0.0868007
		B_n	−5.462568	0.0923653	−0.9120217
8	10.64219	A_n	−13.816050	−0.5935704	0.0059001
		B_n	−5.377480	−0.1194515	−0.8492308
9	11.53233	A_n	−14.182320	−0.7712203	−0.1152458
		B_n	−5.261374	−0.3156642	−0.7711536
10	12.65655	A_n	−14.281540	−0.8962523	−0.2726293
		B_n	−5.119664	−0.4478970	−0.6809696
11	13.85414	A_n	−14.178200	−0.9735180	−0.4362302
		B_n	−4.969800	−0.5193955	−0.5920550
12	14.94000	A_n	−13.99440	−1.0227530	−0.5693875
		B_n	−4.836150	−0.5475780	−0.5162528
13	15.75441	A_n	−13.834280	−1.0587950	−0.6441319
		B_n	−4.734539	−0.5462775	−0.4667917
14	16.23260	A_n	−13.735780	−1.0773440	−0.6649692
		B_n	−4.657769	−0.5136445	−0.4472446
15	16.33507	A_n	−13.723210	−1.0716170	−0.6467648
		B_n	−4.592576	−0.4439938	−0.4589813
16	16.05181	A_n	−13.798150	−1.0364160	−0.6010582
		B_n	−4.534856	−0.3390354	−0.5018743
17	15.48211	A_n	−13.878370	−0.9765938	−0.5322988
		B_n	−4.514590	−0.2232068	−0.5618736
18	14.75425	A_n	−13.861050	−0.8996987	−0.4458971
		B_n	−4.571004	−0.1272728	−0.6238426
19	13.98803	A_n	−13.680650	−0.8143968	−0.3469313
		B_n	−4.724776	−0.7333315	−0.6745811
20	13.25973	A_n	−13.412710	−0.7297177	−0.2486764
		B_n	−4.927793	−0.4689097	−0.7184988
21	12.63616	A_n	−13.169810	−0.6565175	−0.1666053
		B_n	−5.114586	−0.0289250	−0.7611847
22	12.16392	A_n	−13.038360	−0.6012685	−0.1108429
		B_n	−5.233199	−0.0098469	−0.8090585
23	11.80282	A_n	−12.997460	−0.5564108	−0.0727972
		B_n	−5.292338	0.0378381	−0.8576420
24	11.49151	A_n	−13.00144	−0.5112635	−0.0377308
		B_n	−5.314216	0.0865637	−0.9031123

measured and estimated at 6 : 00 AM, the time of which is assumed to give the lowest temperature of the day. Figure 6 shows temperature variation of measured and estimated at 3 : 00 PM. This time is assumed to give the highest temperature of the day. For both cases, the estimated values are in good agreement with the measured.

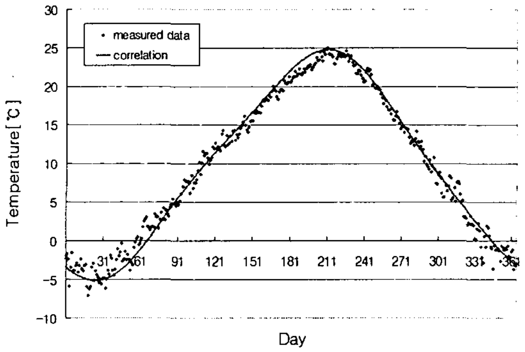

Fig. 5 Outdoor temperature (6 AM).

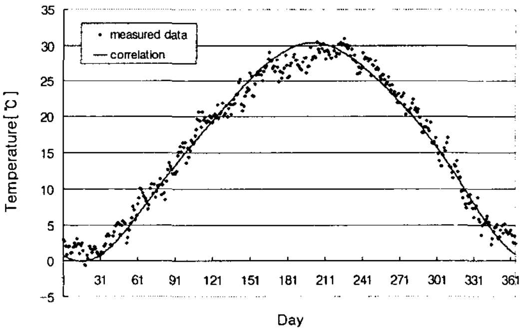

Fig. 6 Outdoor temperature (3 PM).

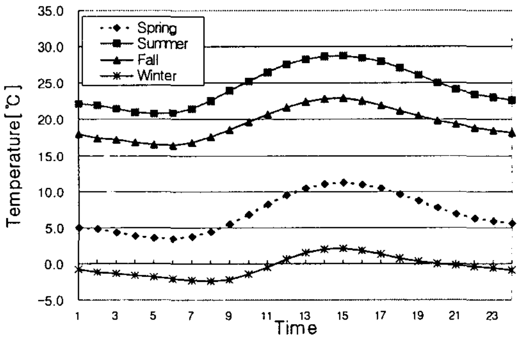

Fig. 7 Outdoor temperature variation of 4 seasons.

Table 5 Coefficients for absolute humidity equation

Time	A_o	Coe.	1	2	3	4	5
1	7.423879	A_n	-6.163508	1.020043	0.2047170	-0.0209962	0.2520577
		B_n	-3.113102	1.695270	-0.5735179	0.1844611	-0.0208383
2	7.431023	A_n	-6.203535	1.039429	0.1905845	-0.0151699	0.2267411
		B_n	-3.105436	1.705863	-0.5866036	0.1933563	-0.0209027
3	7.423421	A_n	-6.236751	1.052288	0.1875861	-0.0168069	0.2044263
		B_n	-3.093800	1.718890	-0.5902953	0.1945724	-0.0219484
4	7.384042	A_n	-6.239767	1.055133	0.1999821	-0.0228686	0.1919511
		B_n	-3.064361	1.721664	-0.5828930	0.1865142	-0.0246202
5	7.337756	A_n	-6.231027	1.053626	0.2151843	-0.0281840	0.1898728
		B_n	-3.023922	1.712436	-0.5685756	0.1725854	-0.0247932
6	7.319911	A_n	-6.239438	1.055715	0.2163927	-0.0270489	0.1971785
		B_n	-2.984446	1.692194	-0.5529919	0.1574395	-0.0171498
7	7.353689	A_n	-6.284130	1.066045	0.1934753	-0.0170067	0.2118558
		B_n	-2.955695	1.663571	-0.5401606	0.1448312	0.0010573
8	7.413603	A_n	-6.345144	1.076042	0.1629726	-0.0085908	0.2278940
		B_n	-2.938620	1.635790	-0.5275816	0.1349185	0.0222941
9	7.462003	A_n	-6.392746	1.073830	0.1480934	-0.0155821	0.2382830
		B_n	-2.931972	1.619720	-0.5111244	0.1269604	0.0364563
10	7.471230	A_n	-6.405829	1.051596	0.1650080	-0.0468113	0.2380741
		B_n	-2.933510	1.623070	-0.4892865	0.1199959	0.0371570
11	7.453606	A_n	-6.397782	1.017788	0.2017353	-0.0913087	0.2305661
		B_n	-2.937030	1.640897	-0.4710759	0.1121823	0.0328796
12	7.431445	A_n	-6.390622	0.984922	0.2392558	-0.1331542	0.2211192
		B_n	-2.935338	1.665099	-0.4681279	0.1014573	0.0358247
13	7.421771	A_n	-6.400260	0.963767	0.2619727	-0.1595531	0.2145038
		B_n	-2.924283	1.688658	-0.4885144	0.0881019	0.0529380
14	7.420443	A_n	-6.418192	0.958121	0.2679790	-0.1702114	0.2131305
		B_n	-2.911898	1.708903	-0.5260526	0.0817736	0.0701451
15	7.418027	A_n	-6.429811	0.970039	0.2587901	-0.1679600	0.2188199
		B_n	-2.909258	1.724250	-0.5709961	0.0944735	0.0681167
16	7.409096	A_n	-6.425038	0.998696	0.2374076	-0.1563082	0.2320363
		B_n	-2.925319	1.734201	-0.6133043	0.1323197	0.0347858
17	7.404248	A_n	-6.411895	1.031738	0.2127780	-0.1414770	0.2478189
		B_n	-2.960560	1.742621	-0.6417606	0.1778986	-0.0128644
18	7.418085	A_n	-6.402933	1.053933	0.1953336	-0.1303658	0.2598504
		B_n	-3.013336	1.754462	-0.6448538	0.2079132	-0.0505881
19	7.457948	A_n	-6.405368	1.054686	0.1923397	-0.1272141	0.2636272
		B_n	-3.078257	1.771526	-0.6167888	0.2062223	-0.0606712
20	7.502122	A_n	-6.405082	1.041945	0.1983931	-0.1256226	0.2619001
		B_n	-3.134932	1.783012	-0.5746327	0.1853079	-0.0515250
21	7.521631	A_n	-6.382619	1.028298	0.2049233	-0.1165323	0.2592334
		B_n	-3.159222	1.774970	-0.5411681	0.1648073	-0.0380921
22	7.497641	A_n	-6.327316	1.024079	0.2050599	-0.0938654	0.2586535
		B_n	-3.135956	1.739497	-0.5334433	0.1598849	-0.0320456
23	7.451898	A_n	-6.263660	1.030614	0.1987324	-0.0634704	0.2570362
		B_n	-3.085842	1.692895	-0.5455677	0.1678116	-0.0319808
24	7.416295	A_n	-6.224931	1.046977	0.1875702	-0.0341772	0.2497194
		B_n	-3.038556	1.657512	-0.5659160	0.1813855	-0.0332229

Figure 7 shows hourly change of outdoor temperature at spring equinox, summer solstice, autumnal equinox, and winter solstice, calculated using Eqn. (1). The outdoor temperature shows this periodic behavior for the same day of the year.

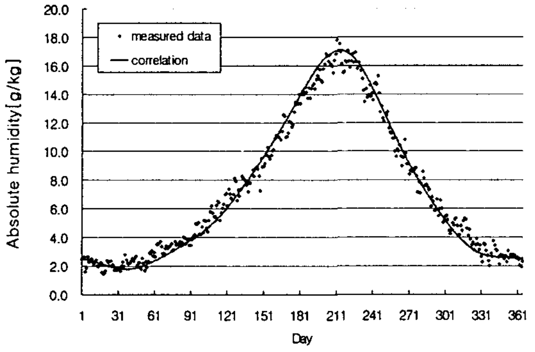

Fig. 8 Outdoor absolute humidity (6 AM).

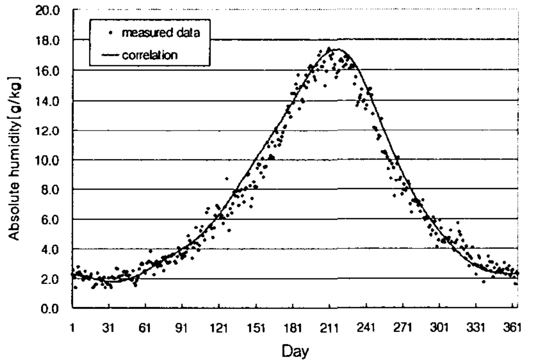

Fig. 9 Outdoor absolute humidity (3 PM).

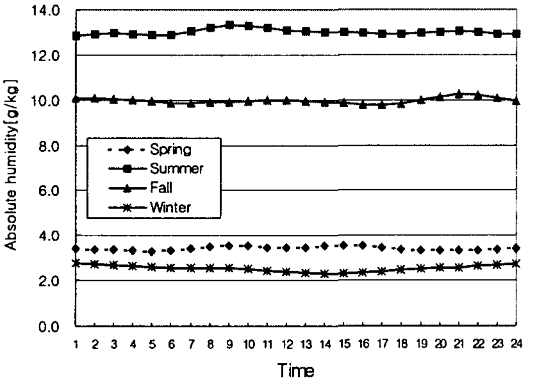

Fig. 10 Outdoor absolute humidity variation of 4 seasons.

4.2 Absolute humidity correlation

Absolute humidity is an important factor in determining the latent load. Absolute humidity is also expressed using Fourier series as given in Eqn. (2). For absolute humidity, however, Fourier series of order 5 is used.

$$AH = A_0 + \sum_{n=1}^{5}\left(A_n\cos\frac{n\pi}{365}x + B_n\sin\frac{n\pi}{365}x\right) \quad (2)$$

Figures 8 and 9 show comparison of measured and estimated absolute humidity at 6 : 00 AM and 3 : 00 PM. Again they are in good agreement.

Figure 10 shows hourly change of absolute

Table 6 Cumulative percentage (%)

Time	2.0℃	1.5℃	1.0℃	0.5℃
1	91.8	81.6	63.3	35.9
2	92.3	80.0	63.0	37.5
3	92.6	82.5	64.1	35.9
4	92.9	83.1	63.0	32.9
5	93.2	84.1	62.7	33.2
6	93.2	83.6	62.5	32.9
7	92.9	81.6	63.9	33.1
8	92.1	80.8	64.1	32.3
9	90.1	78.6	61.1	34.5
10	87.1	76.2	57.0	32.6
11	84.9	73.4	55.9	27.9
12	82.7	69.9	51.8	23.6
13	82.7	67.4	50.4	22.2
14	81.6	67.1	47.4	24.4
15	82.2	67.4	47.1	25.4
16	83.8	68.2	47.4	25.8
17	84.1	69.0	48.8	24.9
18	86.6	74.2	52.1	26.8
19	89.0	75.6	56.1	29.0
20	90.7	77.0	59.7	32.1
21	89.6	77.8	60.3	35.9
22	89.3	79.5	60.3	36.7
23	89.6	81.1	61.9	34.8
24	89.3	81.1	62.2	35.1
Average	88.5	76.7	57.8	31.1

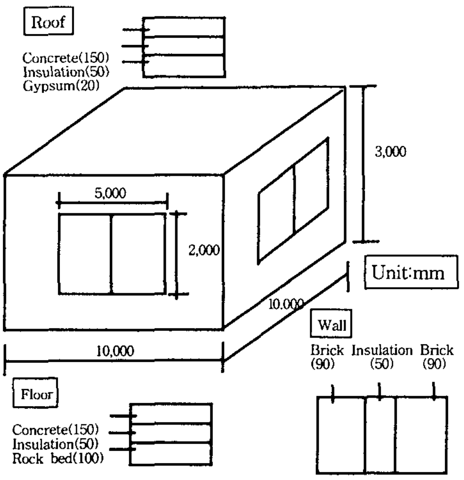

Fig. 11 Simulation model.

humidity at spring equinox, summer solstice, autumnal equinox, and winter solstice calculated using Eqn. (2). The absolute humidity is about 2.5 g/kg$_d$ in winter, 3.4 g/kg$_d$ in spring, 10.0 g/kg$_d$ in fall, and 13.0 g/kg$_d$ in summer, respectively.

Table 6 shows cumulative percentage of data that is within the specified error between the result of empirical equation and measured data. For example, at 1 AM, 91.8% of the data is within 2.0℃ error between measured and predicted.

To show how the weather data affects the cooling and heating loads, simple load simulation is carried out using both standard weather data and weather data generated from the mathematical equation developed in this study.

Figure 11 shows the model of the building. Table 7 shows thermal properties of materials used in the building. The model has a floor area of 100 m^2, a height of 3 m and 2 windows of area 10 m^2 on the east and south walls. A commercial software, TRNSYS version 15.1[5] has been used.

Table 7 Thermal property of materials

Material	Thermal conductivity [W/m℃]	Density [kg/m^3]	Capacity [W/kg℃]
Concrete	2.10	2,400	0.28
Insulation	0.036	30	0.41
Brick	0.62	1,660	0.23
Gypsum	0.35	1,200	0.28
Rock bed	0.63	1,200	0.28

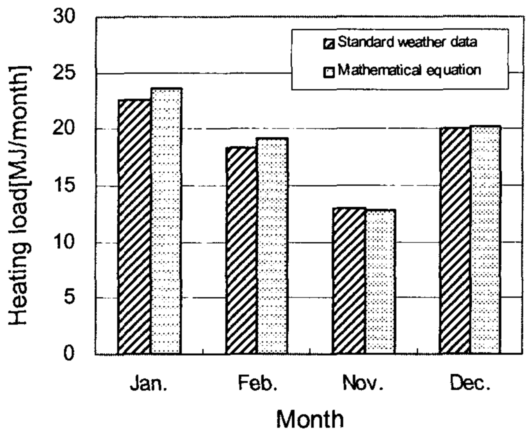

Fig. 12 Comparison of heating load.

The indoor condition is set at 22℃ of temperature, 50% of relative humidity during heating periods. Ventilation air change rate of 1 ACH and infiltration of 0.6 ACH through windows are assumed.

The difference in the results was 0.5~5.4% for heating condition, which is not negligible. Figure 12 shows the difference of a heating load for a month during heating seasons.

5. Conclusions

In this paper, standard weather data of Seoul for dynamic energy simulation has been developed regressing the measured data compiled by KMA during a 10-year period from 1991 to 2000. The standard weather data consists of 8760 values of meteorological parameters such as ambient temperature, solar radiation, absolute humidity and wind velocity.

This paper proposes correlations in the form of Fourier series for determining a set of typical weather data in order to evaluate energy performance of buildings. This set consists of two meteorological parameters: ambient temperature and absolute humidity.

The derived 24 simple mathematical equations can be used for estimating outdoor temperature and absolute humidity conditions for any arbitrary time of the year. The mathematical equations can generate daily and yearly variations of outdoor weather data with consistency unlike the measured data which may show abnormal behavior. Considering that each hour of the day follows a certain yearly pattern, 24 correlations are developed for each hour. The new correlations are easily applicable and can be reliably applied in predicting the long-term performance of buildings, minimizing the error in the estimation.

For further work, other locations beside Seoul should be studied. It is also necessary to develop correlations for other parameters such as solar radiation, wind velocity, wind direction, and cloudiness.

References

1. Bulut, H., Buyukalaca, O. and Yılmaz, T., 2002, New outdoor cooling design data for Turkey, Energy, Vol. 27, pp. 923-946.
2. Gazela, M. and Msthioulakis, E., 2001, A new method for typical weather data selection to evaluate long-term performance of solar energy system, Solar Energy, Vol. 70, No. 4, pp. 339-348.
3. Zhang, Q., Huang, J. and Lang, S., 2002, Development of typical year weather data for Chinese locations, ASHRAE Transactions, Vol. 108, pp. 1063-1075.
4. Kim, D. C., 1996, Development of the Standard Computer Software and Weather Data for Cooling and Heating Load Calculation, Report of Hanil M.E.C. Inc., 94-P-11-03.
5. University of Wisconsin-Madison, Solar Energy Lab., 2000, TRNSYS 15.1.