Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(4):498-503

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Analysis of small and medium-sized public building energy consumption in hot summer and cold winter area

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ABSTRACT

The small and medium-sized public building energy consumption accounted for 60% of the total energy consumption of buildings, energy consumption analysis can effectively regulate energy consumption, improve energy efficiency, and can provide the technical foundation for formulating energy consumption quota and energy saving reconstruction of future public building. Through the monitoring of energy consumption of Anhui province's 29 target buildings, the energy consumption data is in detail. Through statistical analysis of architectural features, construction scale, construction time, in conjunction with other research results, we find out the factors influencing energy consumption of small and medium-sized public buildings in the hot summer and cold winter area. By taking methods to analyze the factors of building energy consumption and the using multiple linear regression analysis, through the gradual optimization, we set up energy consumption prediction model. Through comparison with the measured data, interpretation level of small and medium sized public buildings energy consumption model is higher, and get better prediction results. Compared with similar research, the method has higher accuracy, is more simple and has proposed for predicting the specific model of energy consumption in hot summer and cold winter.

Key words: Small and medium-sized; Public buildings; Energy analysis; Linear regression

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In he current situation requirement of energy-saving emission reduction are increasingly higher, and the construction of low carbon ecological society is becoming more and more important. According to the research, the current Chinese building consumption accounted for more than 30% of total energy consumption. Therefore, building energy consumption has been equal with the industrial energy consumption, transport energy consumption[1-3], becoming the new "high energy consumption".

At present, research of public building energy consumption our country remains to be perfect [4]. In the new building, although most of the buildings in the design phase have been designed for energy saving, but its construction effect, energy consumption level in the operation phase has yet to be tested[5]. For the majority of existing buildings, at present we could only through the electric power department to grasp the overall energy consumption, and for its energy efficiency level, what factors influencing, there is no detailed statistical analysis,so it is not conducive to building energy monitoring and energy-saving reconstruction [6].

This paper takes 29 small public buildings in Anhui province as the target building, has a detailed investigation of their service life, area and function, and has analysed the factors affecting the energy consumption. Through actual energy data of each building within one year as the sample, by the statistics software SPSS for multiple linear regression analysis, we establish the energy consumption forecast model. Comparing between the predicted data and monitoring data, the model fits better for similar construction, and has more accurate prediction results.

1.Research subjects

The 29 goal buildings are located in Ma'anshan,Tongling two city,Anhui Province.Their function include school, office, hotel, hospital, government agencies and other. Sample buildings are located in the hot-summer and cold-winter area,which is one of thermal zones in China.During the coldest month ,its average temperature is higher than 10 ℃,while during the hottest month its average temperature float between 25 and 29 ℃.Its climate is characterized by hot in summer, cold in winter, the air humidity is bigger.When the outdoor temperature is below 5 ℃,if there are no heating facilities, indoor temperature is very low,and not comfortable.

According to the requirements issued by the State Ministry of housing and urban rural development "state organ office buildings and large public building energy consumptionmonitoring system construction guide", we focus on energy consumption monitoring and get the statistics of the architectural features and conditions[7]. By investigating 29 target buildings, recording their basic and regional information,we get the energy consumption data.

2.Influencing factors

According to Zhai Bingxian's research, public building energy consumption was relevant with building envelope, surrounding thermal environment, building area, building density,air-conditioning equipment energy efficiency level, weather conditions, management work time and other factors[8]; CLARIDGE DE thought the public building energy consumption related with building envelope, ratio of window and wall, building area, building function, building density, work time,and equipment quantity[9].Effective factor of public building energy consumption is numerous, we do not intend to make a detailed analysis of those uncertain factors. As a combination of small and medium-sized public construction, seizing the main influencing factors, and to simplify the analysis of energy consumption model,so we take regression analysis through 29 buildings energy consumption data for 12 months as a sample, the main influence factors are determined as follows: the construction area, the number of use years, building function.

3. Model establishment and analysis

We take building energy consumption as the dependent variable Y,and these variables (factors)are set up for X1,X2,... , Xn.It is assumed that the dependent variable has a linear relationship wiht the respective variables,using multiple linear regression analysis,and could get the model as follows:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+e$$

In that, β_0 stands for constant coefficient of regression, $\beta_1,\beta_2,\ldots,\beta_n$ stand for coefficients of regression, e stands for regression residuals. Influence factors contain: building function as X_1, construction area as X_2, the use time as X_3 (the year 2013 as the cut-off year). Among them, building function is due to multi classification variables, the variable X_1 is represented by two sub variables gn_1, gn_2.When function of a public building stands for the school or office,it is assigned that $gn_1=0$, $gn_2=0$; when function of a public building stands for hotel, hospital, or shopping malls, it is assigned that $gn_1=1$, $gn_2=0$; when function of a public building stands for government office, it is assigned that $gn_1=0$, $gn_2=1$.

Taking 2013 annual energy consumption data and building information statistical results of 29 buildings as a sample,we analysed by SPSS13.0 software. Using Setpwise analysis step by step regression analysis, with 95% confidence level of F significance test,standard error bounds for (2, +2) [10-11], the results list in table 1.

Table.1 The regression model summary of sample data of 29 buildings

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.466(a)	.217	.157	1937259.92337	
2	.916(b)	.838	.819	897685.02404	2.855

a Predictors：(Constant), gn_2, gn_1
b Predictors：(Constant), gn_2, gn_1, area

It can be seen from table 1: there are only two factors which are architectural function and architectural area entered into the equation by F test. The R value is 0.916, R2 value is 0.838, namely 83.8% of building energy consumption can be explained by the model,so fitting degree is better. Check the standard residuals (see Figure 1): transverse coordinates Y stand for the actual annual energy consumption of building sample, the longitudinal coordinates stand for standardized residuals corresponding (mean / standard residual = residual residualstandard deviation) [11-12],we found that predictive residual value of 3 super large public-building which their annual energy consumption values exceed 4000000kW.h is too large, they are abnormal points.Therefore, this model is not suitable for the prediction of the building which its area is larger more than 40000 m2. So,we delete 3 large public buildings which are Dahua International Plaza, overseas Crown Plaza

Hotel, Maanshan Iron and steel production command center. Continue to carry out regression analysis, there are still only two factors in fit-test list by F test into the model: building function, building area, and the R2 value is 0.958, the fitting degree is greatly improved, as shown in table 2. In the analysis of the results of the 26 samples, the standard residual although mostly lies in (2, +2), but there are 1 points greatly exceeded the scope, as shown in Figure 2,so the corresponding point of Tongling city Real Estate Hotel is deleted.

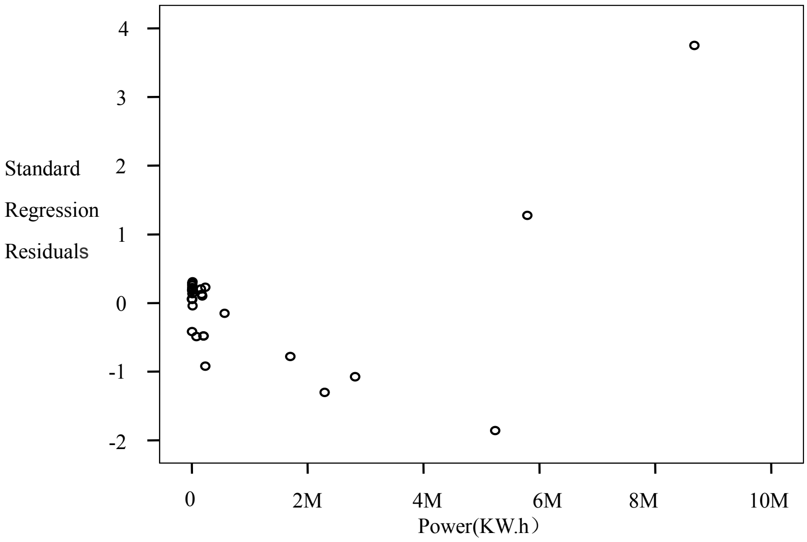

Figure.1 The standard regression residuals of 29 buildings

Table.2 The regression model summary of sample data of 26 buildings

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.596(a)	.355	.299	617820.37413	
2	.979(b)	.958	.952	161638.83880	1.827

a Predictors：(Constant), gn_2, gn_1
b Predictors：(Constant), gn_2, gn_1, area

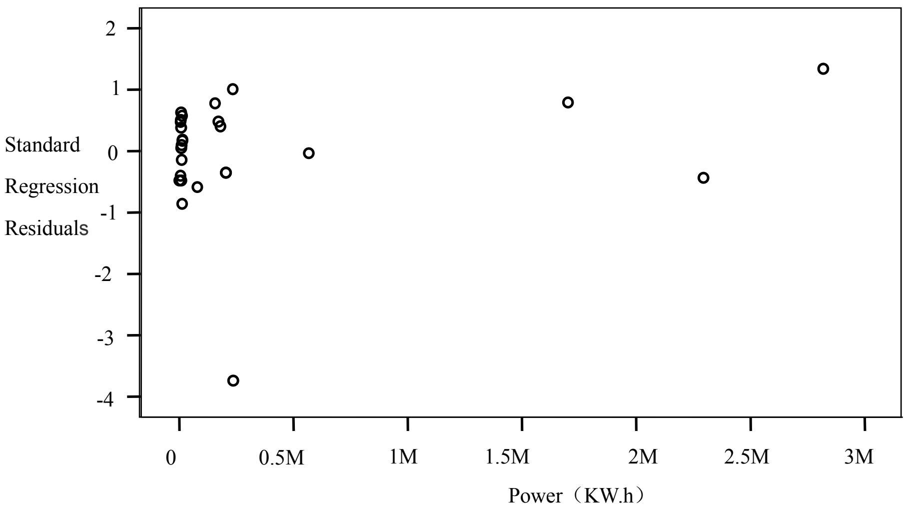

Figure.2 The standard regression residuals of sample data of 26 buildings

Through regression analysis, after 4 samples of excessive energy consumption and residual slants big removed, we get the final sample data.It can be found through observation that 90% of the rest sample buildings are small and medium-sized public buildings which are smaller than 10000 square metres.

With 25 new samples we take multivariate stepwise regression analysis again (see Table 3), and found that the 2 variables entered into the model by F test ,during which building function is the first to enter the model of the building energy consumption, followed by the construction area. The use time did not enter the model. In the

A, B two model, the B model of the R and R2 values is higher, respectively 0.995 and 0.990, showed that when the interaction of building function, building area take factors, 99% changes of variables Y through regression relationship could be explained[12].

The linear regression tolerance coefficients in the regression coefficient list (see Table 4) was more than 0.5, so there is no serious multicollinearity problem. Observe the collinearity check list (see Table 5), the characteristic roots are not equal to 0 and not same each other,condition indexes were not greater than 30, so the regression coefficients can be obtained by regressing test, there is no collinearity problem[13]. So we could now get the final regression model(see Table 5):

$$Y=-107014.491+45414.193gn1+48731.658gn2+74.409X2$$

In the formula, Y represents a public building annual energy consumption value; gn1, gn2 stand for the building function; X2 says the building area. The use time as an influence factor of building energy consumption did not enter the regression model, because on the one hand public buildings mostly are used in the past 10 years,there enclosure structure and types of structure have little change and smaller impact to energy consumption; on the other hand, in recent years, as the implementation of mandatory energy-saving standards for new buildings is executed better, existing energy-saving building scope extended,it has greatly reduced the effect on building energy consumption.

Table.3 The regression model summary of 25 sample of office building

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.596(a)	.355	.296	631637.10728	
2	.995(b)	.990	.989	79276.00595	2.142

a Predictors：(Constant), gn_2, gn_1

b Predictors：(Constant), gn_2, gn_1, area

Table.4 Regression coefficients of 25 samples of office building

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	9605.091	190445.754		.050	.960		
	gn_1	1034420.338	305392.612	.630	3.387	.003	.849	1.178
	gn_2	179331.481	305392.612	.109	.587	.563	.849	1.178
2	(Constant)	-107014.491	24108.539		-4.439	.000		
	gn_1	45414.193	46692.638	.028	.973	.342	.572	1.748
	gn_2	48731.658	38490.860	.030	1.266	.219	.842	1.188
	面积	74.409	2.006	.983	37.089	.000	.657	1.522

Table.5 Coefficients collinearity diagnosetics

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	gn1	gn2	area
1	1	1.748	1.000	.13	.09	.09	
	2	1.000	1.322	.00	.31	.31	
	3	.252	2.636	.87	.61	.61	
2	1	2.278	1.000	.06	.05	.02	.06
	2	1.129	1.420	.03	.07	.34	.04
	3	.363	2.504	.38	.10	.15	.67
	4	.229	3.156	.52	.78	.48	.23

To observe standard error (see Figure 3), the distribution random in 0 and both sides fall in (2, + 2) range, the regression residual of equation is small, the regression model has good prediction. At the same time to observe predicted value and the actual value(see Figure 4), they were 45 degree linear positive correlate which stands for good-fit. Meanwhile, with a certain number of sample test,it proved the equation was validated very well.

In 29 public buildings, the 4 buildings are shaved, which including: a commercial building of over 40000 square meters, a hotel building area of over 50000 square meters, a large government office buildings, a building for office and production of more than 70000 square meters. Those buildings have diffrent function, the influence is different, and the sample data is too small to do regression analysis,so they are not discussed.

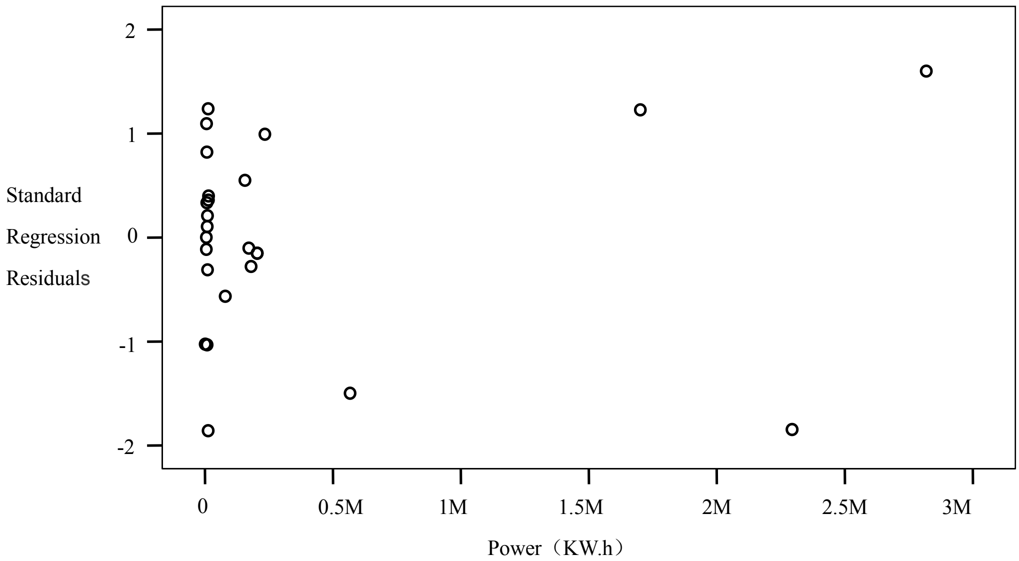

Figure.3 The regression standardized residuals of sample data of 25 buildings

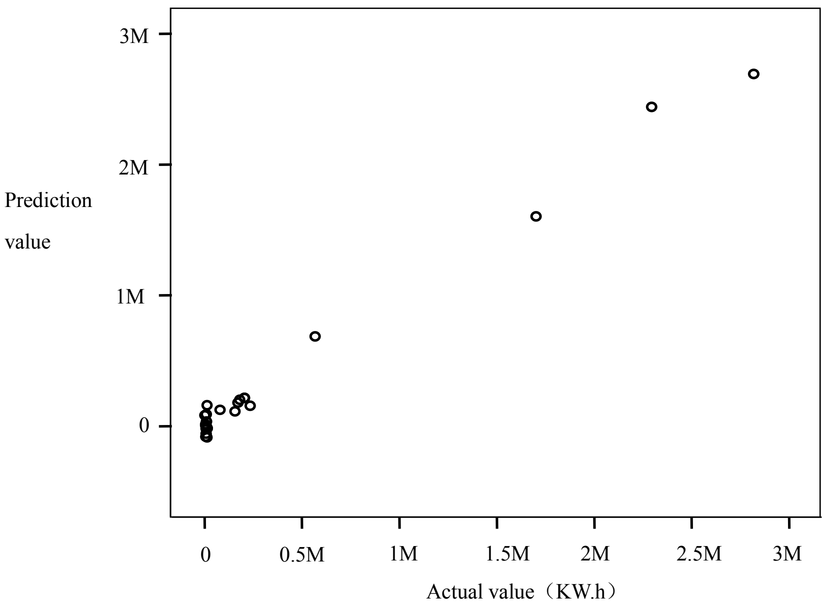

Figure.4 Prediction value and actual value of 25 sample buildings

CONCLUSION

①Using multiple linear regression method we made analysis on building energy consumption of small and medium-sized public building energy consumption in hot summer and cold winter area. In the course of analysis, according to the building function classification, considering the influence of construction area and use time,we set up the regression model of high precision, and it was verified well.

②In the model, we discovered that the main influencing factors of small and medium-sized public building energy consumption are building function and building area. After verification, the model has good energy consumption prediction effect. Energy consumption prediction model for forecasting data, can be helpful for energy consumption quota, energy policy, and could provide scientific and reasonable basis for all kinds of energy saving and energy conservation supervision.

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