

The material consumption Estimation model of Frame shear wall structure

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Abstract. In the construction of the project cost, the cost of raw materials account for about 60%. Reducing the consumption of construction material is the key to control the project cost. If you can estimate the consumption of construction materials effectively before the construction, it can provide the base for cost-effective and timely achievement of organizational goals. In this paper, through the investigation, I collected 23 civil buildings construction materials of each index, based on multivariate statistical regression analysis, using SPSS software to calculate, established the frame shear wall structure of steel, concrete, block consumption model of three main building materials. At the same time, choose five samples in other place to verify this model. After verification, the model can estimate roughly the structure of the three materials consumption. The model is suitable for the proposal stage, the conceptual design stage and preliminary feasibility study stage. It has a certain value to calculate building the main material consumption, and is advantageous to the actual construction cost control.

Keywords: Material Consumption, Frame Shear Wall Structure, Regression Analysis, Tall Building

1. Introduction

In engineering projects, the cost of raw materials accounted for more than 60% of the engineering cost [1], so reducing the consumption of construction materials is the key to reduce the construction cost.

Building and construction projects are highly technical in nature, specificity and complexity of the many units involved, a long construction period. Due to

projects have such characteristics, so the engineering calculation of material consumption also has the characteristics of the complexity and specialization. Since that is so, many domestic and international scholars carried on a great deal of empirical research to this field. Such as: Kanit Recep et al. used the method of regression analysis, analyzed the office building of the relationship between the concrete and steel consumption and its strength to establish the office building of the consumption of concrete and steel model [2]; Zikui Lin et al., used hybrid neural network method to establish a model for predicting accurately railway material consumption, it has a very good practical value [3]. Xinli Zhang et al., used the projection pursuit regression method to establish multivariate input single output variable multiple regression model, calculate construction material consumption, use genetic algorithm to optimize model. Projection pursuit regression estimation parameters can be quickly and efficiently calculate the quantity of construction project [4]. Xianguo Wu et al., applied the neural network theory to residential buildings of the main consumption quantity calculation, set up the application of multilayer feedforward neural network model of BP algorithm, the practice has proved that this model can realize quick estimate consumption quantity [5].

The regression analysis is an advantaged tool to process dependency relation between variables and applicable in many domains. It is a process variable correlation between mathematical statistics method and can seek environmental events law of science and predict its development trend. With its simple principle, limited parameter and its easy implementation, it has been used widely now in many areas. Such as: Xiaobo Qin et al., analyzed the rice field control greenhouse gas emission flux affected by various factors using multiple regression analysis, revealed the greenhouse gas emission flux and environmental factors of relationship[6]; Wenbing Sun et al., used multivariate linear regression to established the main physical and chemical indicators and wine grape wine quality relationship model[7].

The project is complexity dynamic, disposable, one-piece, the life of the cyclical and other features makes the project quality management and control have its own unique characteristics. Calculating the engineering material consumption is complex, but even the different types of buildings, their modeling and the function are not very big difference, and the design theory, construction method, construction materials, and even cost calculation method are all interlinked. The starting point of this paper is to put aside the complexity of the buildings, excluding special factors, to seek their regular consumption of building materials. The article selected the method of multiple regressions to

establish statistical model of the application. While in the actual construction, the experienced engineering cost personnel have the ability to estimate the building materials consumption, however, without a standardized estimate model, it usually leads a great deviation for the estimation. By establishing the model estimation, it not only can reduce the cost of the staff workload. Meanwhile, it is also conducive to non-professional personnel to understand the structure of the material consumption and cost.

With the advancement of urbanization, the demand of the high-level structure is increasing. So the shear wall structure system has been widely used in high rise flats for its advantages of flexibility of arrangement and lower cost. This paper is on the basis of a large number of frame shear wall structure indicators of real data, an estimation of the three main materials was built, and this model can be used in estimating project construction cost roughly.

2. Frame shear wall structure

2.1. The characteristics of the project

1. In terms of comparison between different buildings, in most cases, the external shape, function, structure, space layout, and even the construction site, environment, etc., vary highly. This is the structure of the Singleton. Building products of Singleton determines that each project must be separately calculated cost.

2. In terms of individual buildings, the material that constitutes building entities is numerous and the models are complex. Meanwhile, building entities involved with wide range of engineering, so to measure the structure of the construction cost in detail and accurately is a both time-consuming and laborious work. At the same time, the engineering cost calculation is a combination of division, it related to the combination of building construction [8].

2.2. Frame shear wall structure

The framework of the wall structure is also known as frame structure, it is suitable for vertical layout of the complex or flat, greater horizontal load for high-rise buildings. Frame-shear wall structure is the arrangement of a certain number of shear wall in frame structure, thus it consists a flexible use of space and meets the requirements of different building function. Meanwhile, it also has enough shear wall, a pretty big stiffness and mechanical characteristics of frame shear structure, which are made up of frame and shear wall structure

consisting of two different structures to resist lateral force new form of stress, so it is different from the pure frame structure of the framework, the framework of shear walls in frame shear structure is different from the shear wall shear wall structure. Space frame shear wall structure stiffness is very big, space integrity is good, the room is not exposed beams and columns edges, facilitate indoor layout, convenient and practical. It is a kind of residential building that is most widely used structure form. [9]

2.3. Frame shear wall structure commonly used materials

There are three materials to constitute a construction entity: concrete, block and steel. [9]In frame shear wall structure, these three materials accounts for a large proportion, therefore, on the basis of the three kinds of materials, through the estimation, the whole building material consumption can be determined, and then estimates the whole project construction cost of the project [10].

3. Regression analysis model of frame shear wall structure materials consumption

3.1. Regression model concept

Regression analysis is a method or theory to study one variable on another (some) variables dependencies. Starting from a sample data, confirm the mathematical relationship between variables and test credible degree of the relation between various statistics .Then though the influence of a particular variable variables to find out the influence of which variables significantly, which was not significant. Using the equation, according to the value of one or a few variables to predict or control the other of a particular variable values, and this can acquire the prediction or control accuracy.

3.2. The advantages of regression analysis model

1. The regression analysis method using for the analysis of multi-factor model is more simple and convenient.
2. Using the regression model, as long as the same model and data, with standard statistical method can compute the only result.
3. Regression analysis can accurately measure the factors and the related degree between the fit of the regression of high and low to improve the effect of prediction equations.

3.3. The faults of regression analysis model

The establishment of regression model considers general character of the building, ignoring the individuality of each building, it will cause greater error when the model applied to modeling a special buildings.

3.4. Regression analysis model is established in this paper

Model assumption:

1.The consumption of masonry structure does not consider the masonry mortar, such as structural reinforcement of volume.

2.Calculating the concrete consumption does not deduce the volume of steel.

3.Calculation of quantities adopts the unified national construction basic norm.

4.Selected samples are civil constructions. The layer height is more than twenty miles.

5.Building of the ground and underground part is on the basis of ± 0.000 boundary.

6.In order to make the model representative, buildings are the basis of selecting raft foundation.

This article selects 23 residential building of framework wall structure. The 23 building construction unit height is 2.8 m and the underground number 1 layer.

Frame shear wall structure is mainly suitable for high-rise buildings. For frame shear wall structure, the ground part of the material consumption and underground part of the material consumption has a very big difference, so the selected samples of the structure is divided into the ground and underground structure.

The sample structure is divided into the ground and underground structure. Select the construction area and construction area of underground as independent variable X1 and X2, with the steel consumption, the amount of concrete and dosage of block as the dependent variable Y1, Y2, Y3, regression models were established. Here in reinforcement of regression model as an example, the results using SPSS statistical analysis software for data processing are as follows:

Tab. 1: Model Summary

model	R	R square	Adjusted R square	Std. Error of the Estimate	Change Statistics			Durbin-Watson
					F Change	df1	df2	
1	.998a	.996	.995	16.70476	2329.88	2	20	1.610

From the table model aggregated, adjusted R-squared of 0.995. This shows that variation due to all the variables Y1 through independent variables in the regression coefficient is the proportion of independent variables explained 99.5%. It shows the ratio that all quantity can through the regression coefficient of the dependent variable explained by the independent variable is very high. And the DW is 1.61, which indicates a good independence from the variable. So as to validate the structure of the building area can be divided into the feasibility of aerial part and underground part.

Tab. 2: Anova

model	Sum of squares	df	Mean square	F	Sig.
Regression	1300139.864	2	650069.932	2329.588	.000a
1 Residual	5580.986	20	279.049		
Total	1305720.850	22			

From the table, F is 2329.588. sig is 0. It indicates the regression equation makes sense.

Tab. 3: Coefficient

model	Unstandardized		standardized	t	Sig.	Collinearity	
	coefficients		coefficients			statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-27.164	8.796		-3.088	.006		
1 X1	.213	.033	.274	6.395	.000	.116	8.608
X2	.036	.002	.736	17.150	.000	.116	8.608

Can be obtained from the table, the regression equation is:

$$Y1=0.213X1+0.036X2-27.164$$

Verify whether the regression equation makes sense:

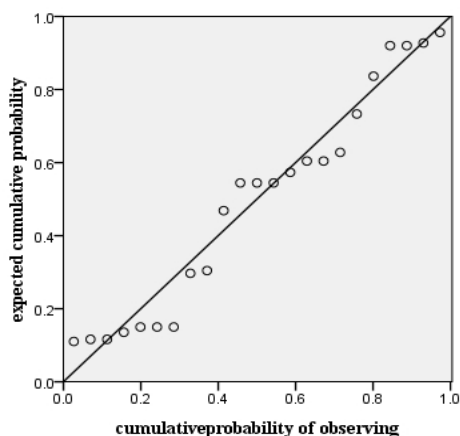


Fig. 1: Standard p-p figure

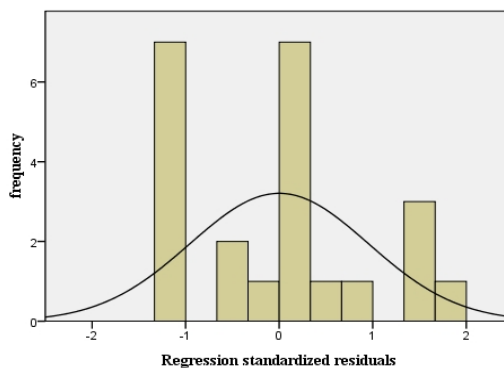


Fig. 2: Histogram

Standardized residuals histogram basic accords with normal distribution, standardized regression P - P figure base is located in a straight line, it shows that the regression equation is meaningful.

Similarly, the other two can be calculated from material consumption estimation model. Three material consumption models is (where Y1, Y2, Y3 represent steel, concrete, masonry consumption, X1, X2 represent the underground area and floor area of the building):

$$\begin{cases} Y1=0.213X1+0.036X2-27.164 & (1) \\ Y2=2.315X1+0.277X2-447.960 & (2) \\ Y3=0.149X1+0.143X2-0.003 & (3) \end{cases}$$

We can see steel, concrete, masonry and construction area of consumption has a direct relationship from the model, which is due to the construction characteristics of the frame shear wall structure.

1. Frame shear wall structure, the three major building materials consumption of main components, such as cutting plate, beam and slab are horizontal component, their number and location is related to the structure of the building area directly.

2. Masonry structure is vertical structure, but due to its length is greater than the width, thus it affected by the construction area.

3. All related to the construction area of the component of the structural components of the building account for a large proportion of the total.

4. Model validation

After the construction of the model, the model is used to calculate the specific project example, the calculation results of the comparison model and the actual budget amount of differences, so as to verify the feasibility of the model.

This paper selects 5 samples with the regional different samples to validate the model. So that to improve the applicability of the model. Table 4 is the basic information of the sample.

Tab. 4: samples of frame shear wall structure characteristics and material consumption

project name	Underground construction area	ground construction area	type of building	Structure type	Reinforcement amount	Concrete amount	Masonry volume
sample1	726.81	10506.56	Residence	Frame-wall	512.158	4292.64	1469.37
sample2	1764.47	6426.82	Residence	Frame-wall	539.944	5145.45	1047.045
Sample3	1182.46	21384	Residence	Frame-wall	1153.97	9967.5	3207.62
Sample4	1113	13403	Residence	Frame-wall	764.42	6684.42	1613.63
Sample5	1254	13752	Residence	Frame-wall	613.55	5229.04	2177.46

Use the material consumption model to calculate the consumption of three kinds of material and material the actual budget amount of comparative analysis in the following table.

Tab. 5: Budget value compared with the model values analysis

Project Name	Reinforced Steel mold			Concrete mold			Masonry		
	Type	pre-Calculated value	Relatively Error	Type	pre-Calculated value	Relatively Error	mold Type	Pre-Calculated value	Relatively Error
sample1	505.88	512.15	0.0119	4144.92	4292.64	0.0344	1610.73	1469.37	0.0962
sample2	576.099	539.944	0.0669	5145.45	5417.02	0.0501	1181.93	1047.045	0.1288
sample3	1153.97	994.52	0.138	9967.5	8212.80	0.176	3207.62	3234.09	0.0002
sample4	764.42	692.41	0.09	6684.42	5841.27	0.126	1613.63	2082.43	0.2
sample5	613.55	735.01	0.19	5229.04	6234.35	0.19	2177.46	2153.38	0.011

In order to compare the three materials budget value more intuitively, the model values curve are as follows:

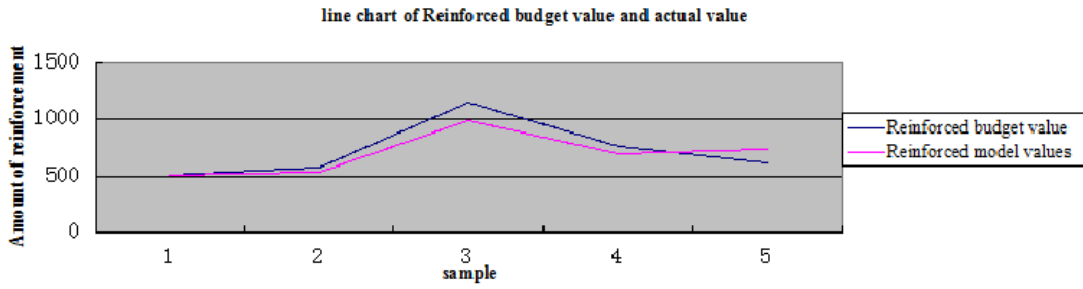


Fig. 3: line chart of Reinforced budget value and actual value

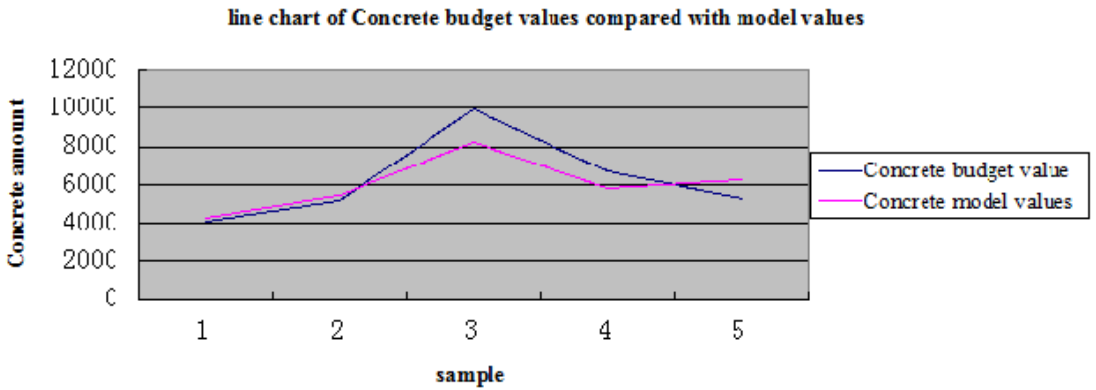


Fig. 4: line chart of Concrete budget value and actual value

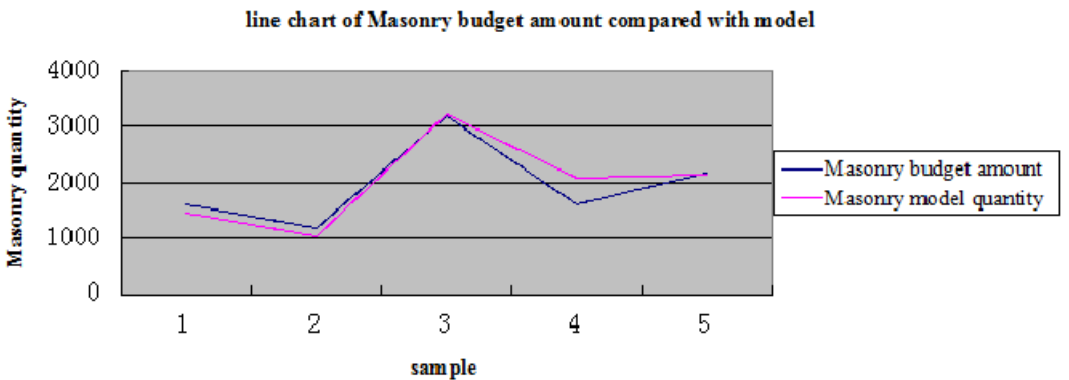


Fig. 5. line chart of Masonry budget value and actual value

From Table5 and Fig3, 4 and 5, estimation model can predict the three

materials consumption, and prediction error is within an acceptable range. From each kind of material in the line chart can be very intuitively seen budget value with the model of alignment is higher. The difference is due to the actual building process design resulting vary. This paper only select five samples verification, but also has certain representativeness.

5. Model improvement and revision

5.1. The influencing factors of model establishment

1. The influence of the design specification. Linear regression model of the original data come from actual design drawings, the drawings are to meet the requirements of the corresponding design specification. And the change of the design specification requirements will directly affect the structure of the material consumption, such as earthquake resistant level increase, the level of concrete and steel reinforcement ratio, anchorage form has changed, these will directly affect the consumption of building materials.

2. The influence of calculation accuracy. Since the statistical method was adopted, so the number of samples of the establishment of a statistical model, and the accuracy of the model has a very important influence. According to the probabilistic and statistical view, the more samples, the more beneficial to the improvement of the accuracy of model. In addition, in the process of model building, it needs to measure materials consumption of each sample of a single building, precision measuring accuracy will affect the entire model.

3. The difference between each building. Linear regression model using the statistical analysis method, at the same time of using this method, the subjective ignores the difference between a certain degree of individual buildings, and more is in common between them as a representative value for this series of buildings. In the reality, there are no two identical buildings, so to measure the personality of simpleness, the generality of the groups will always appear more or less error.

5.2. Improvement of the model

In view of the factors affecting model mentioned above, it can adopt the following method to improve the model:

1. With the revision of the specification, in a timely manner to improve the model, to ensure the efficiency of the model.

2. A lot of collecting actual building drawings timely, for accurate measurement and statistics, then compared the actual value with the model

values, deviated analysis, so that to improve the model.

3. When a single building's actual consumption and the model calculation value have bigger difference, and cannot be directly modified calculation model, can adopt the method of coefficient of correction:

$$T'(x) = M * T(x) \quad (4)$$

T (x) is for the model calculation values, refers to according to the linear regression model, and it is concluded that the numerical x stands for a certain material consumption; M is as the correction coefficient, used to reduce the model calculation values (T) and the difference between the actual value (R); T'(x) is for the revised model, which makes the calculation structure model is more close to the actual situation.

The obtaining of M coefficient still relies on statistics analysis method. The statistics in the process of model of using the T value and R value is large (generally refers to difference is greater than 10%), the $M = R/T$, according to the different characteristics, such as the structure type, function, respectively of the M value is more than statistics, then they are average, calculated using the average.

6. Model application

Calculation model of this paper are used to get the building of the three materials consumption (Y1, Y2, Y3), multiplied by their comprehensive unit price respectively (P1, P2, P3), and then use them and different categories of the proportion relation between the engineering cost, calculate the different content of take the project cost. Such as: reinforced Sectional works of frame shear wall structure buildings accounted for the proportion of the total cost of the civil engineering (P) is 28% ~ 37%, the consumption of steel can be produced by:

$$C = Y1 * P1 / P \quad (5)$$

When there is multiple C, choose the larger one to ensure that the model calculation results of actual project cost effective control.

This article selects a building called seasons to verify it.

Project summary: the building is a frame shear wall structure residences, its foundation is raft foundation. It is the flat roof, the construction area is 15471 m², the upper number is 24, its basement is 2 layers. The ground construction area is 1428 m², underground construction area of 1186 m², construction of the total cost is 20191909 CNY.

Using the model to estimate for the cost of the building is as following:

Calculated by using the model of the building steel consumption

$$Y1=0.213*1186+0.036*14285-27.164=739.714t$$

Reinforced the comprehensive unit price is about 7900 CNY/t(The data from engineering survey)

$$P1=7900$$

In practice, however, in order to better control the cost, $P=28\%$

The construction of civil engineering total cost is estimated to be

$$C=Y1*P1/P =739.714*7900/28\%=20870502\text{CNY}$$

The error of the results is 3.36%.

From the results, the error of the estimate value and the actual budget is in a reasonable scope. Thus it can be seen from the model has a certain reference for the early stage of the project cost control.

7. Conclusion

This paper applies the method of multivariate statistical, based on the perspective of mathematical analysis, frame shear wall structures of the ground part and underground part area and area of reinforcement, concrete, block three building materials consumption, can be roughly estimated consumption of three building materials, so as to provide the basis for the materials department stock the system strategy, it has certain practical value.

Using regression model to estimate frame build wall structures, calculation is simple, it just needs to know the building area, so the calculation accuracy is not high, this model is suitable for project proposal stage, the conceptual design stage, and the preliminary feasibility study stage.

Roughly calculated by using the model of the structure of the three materials consumption, not only can make the material plan timely, but also through three main materials comprehensive unit price to a roughly estimate the structure of the construction cost, it has certain guiding significance to the corresponding project tender stage, meanwhile, it can effectively control the project cost. Compared with foreign instance model, the advantages of the model is simple and intuitive, and laypeople can also estimate the project's cost.

Because of the limited conditions, the settlement amount doesn't collect the settlement amount of these buildings, but the budget amount. In actual construction, the settlement and the budget have a certain gap. If analyzed with the settlement, the model will be more practically significant. It will continue to improve in the subsequent work. At the same time, in the later work, I believe is I can collect a large number of drawings, then using the parameter estimation method and engineering example analysis method to analyze the frame shear wall structure engineering materials. Comparing the three kinds of methods,

analyzed the different estimation model respectively. The types of engineering have guiding significance for such model, so it has a wider range of application.

The analysis of the collecting data in practical engineering can improve the model. And we can analysis the project characteristics of the different applicable model improvement method, to improve the applicability of the model.

Along with economic development and technological progress, engineering structure will also change. The model could be changed with the actual project to keep pace with the Times. The analysis method of the model is also applicable to other types of structure, through a lot of the same type data analysis, model can be concluded that this type of application.

In addition, saving material consumption not only starts from the quantitative methods, but also should pay more attention to the daily work of material management and construction organization plan.

Acknowledgements

First of all, I would like to extend my sincere gratitude to my supervisor, Xuedong Chen, for his instructive advice and useful suggestions on my thesis. He has walked me through all the stages of the writing of this thesis. Without his consistent and illuminating instruction, this thesis could not have reached its present form. I am deeply grateful of his help in the completion of this thesis.

I am also deeply indebted to all the other tutors and teachers for their direct and indirect help to me.

Special thanks should go to my friends who have put considerable time and effort into their comments on the draft.

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