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Modeling the Relationship of Architectural and Structural Design Variables for Estimating Substructure Cost of Duplexes

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Abstract
In-complete project definition at schematic design phase create difficulty in obtaining tangible cost estimate. This research work attempted to establish a time saving quantification model of architectural and structural design relationship for faster estimation of cost of concrete in column bases of residential duplexes. It collated substructure cost predictive variables of 30 residential duplexes from participating construction and cost professionals and crafted and validated from analyzed statistics 5 predictive models for quantifying cost of substructure concrete. It established among others that volume of concrete in column base cannot be estimated from linear regression model based on block work girth alone, but from a multiple regression of floor area and block work girth. It recommended the evolved model as adequate and fit for the forecast of volume and cost of concrete at column bases at sketch design stage when there is no detailed plan.

Keywords: Model, Cost estimation, Concrete, Substructure

1.0 Introduction
The quantity surveyor is often required to provide an estimate of cost and value of a project at inception when project requirements are undefined, or at best provisional.

Quantity Surveyors at sketch design stage are required to predict cost in order to ensure that the project cost falls within clients approved budget. Most Quantity Surveyors use hunch or discretion to assign values to some structural engineer's details not available in the architectural drawings when producing approximate cost estimate. This research attempts to develop a model of architectural and structural design relationship which will enable a faster and more accurate generation of approximate estimate.

It focuses precisely on evolving a model based on Approximate Quantity Estimating techniques which attempts to estimate cost of column base concrete before significant foundation design work is done. The model would help ease the high pressure scenario in which most construction estimators often find themselves and would add to the progression in the development of cost models.

2.0 Literature
An Estimate is a calculation of the quantities and costs of various items of work required in a project. The estimated cost of work is deemed to be a close approximation of its actual cost. The closeness depend on accurate use of estimating methods and correct visualization and definition of total work requirement. Underestimation of cost results in unpleasant shock leading to change orders or project modification or even abandonment.

While over-estimation, cast doubt on the competence and expertise of the professional Quantity Surveyor/Cost Engineers or Estimators involved as the cost adviser and manager of project.

Data required for preparing estimate include; plans, sections, elevations and other details/specification indicating the exact nature and class of material to be used and the rates at which different items of work are carried out. The purpose of estimating is to give the client reasonably accurate idea of the project cost to guide his decision to undertake, curtail or drop the proposal depending on funds available, direct and indirect project benefits.

Two main groups of estimating techniques for building project are;

1. Approximate Estimating- this include functional unit, cube, floor areas, storey enclosure, elemental cost and approximate quantity methods and are used at varying levels in the definition of project costs before substantial/full definition.

2. Detailed estimate- which determines the quantities and costs of everything that the contractor has to execute for satisfactory completion of the work, following a standard method of measurement (SMM) guide. It is rigorous but the best and most reliable form of estimate when the project is reasonably or fully defined.

The approximate quantities estimating method involve substantial work as well, and are regarded as the most reliable and accurate of the approximate estimating techniques. Depending on the experience of the surveyor, measurement can be carried out fairly quickly using composite rates to save time [1, 2].
The rules of measurement are simple, although not standardized and may vary from one cost practitioner to another;

- Popular approach involves grouping together items corresponding to a sequence of operations and relating them to a common unit of measurement unlike the measurement for a bill of quantities where items are measured separately.
- Composite rates are then built up from the data available in the office or from market survey, for that sequence of operations.

Initially, the composite rates require time to build up, but once calculated they may be used on a variety of estimating needs. Reasonably priced software packages are now available for use. They are good at the data collection, computation and clerical aspects of estimating. They achieve and retrieve large volume of resources, cost and productivity information, perform calculations quickly and accurately and present result in an organized, neat and consistent manner [3].

2.1 Cost Model

According to history, the development of cost models can be classified in three different groups; the first-generation models originated from functional elements of building oriented cost planning approach in England at the end of 1950's and was extensively used until the end of 1960's [4].

The second-generated models derived from the regression analysis and have been used since mid 1970's [4].

The third–generation model started to develop in the beginning of 1980's and generally based on Monte Carlo simulation technique [5]. This later models have encompassed expert systems.

2.1.1 Bill of Quantity as a Traditional Cost Model.

The bill of quantities is an example of a cost model, but the bill is prepared at a very late stage in the design process hence information obtained from changing the quantities or the price rate of items on the bill would come too late to give the client an indication of his likely cost commitment at the outset of the project or allow meaningful early control to be properly exercised. There is therefore an obvious need for a much simpler model at an earlier stage in the design to overcome these problems.

2.2 Concepts of Cost Model

According to [6], "cost model is the symbolic representation of a system, expressing the content of that system in terms of the factors which influences its cost". Also [7] ascribed cost model to a procedure developed to reflect, by means of derived process adequately acceptable output for an established series of input data. According to [8] cost model is a technique used for forecasting the estimated cost of a proposed construction project.

In using cost model, the data is collected, analyzed and updated. New data collected at implementation of a model are appended to the previous data.

A cost model can be deterministic or probabilistic. In deterministic, the input variables for the cost model are exactly known. In probabilistic, the variables are not absolutely certain but can be calculated. Many researchers [9, 10, 11, 12, 13, 14, 15, 16, and 17] differentiate traditional and non traditional cost models depending on the model characteristics. The traditional mono-priced cost estimation model used in the schematic design phase include unit, square, cube and building envelop models. The traditional resource-based models using functional elements and building operational units are applied in the construction phase.

The non-traditional model, encompass new techniques and practices e.g. experimental model, regression and simulation models.

The study of [18] identified factors which contribute to project cost, and constructed a predictive project cost model using the principal component technique that assesses the relative importance of determinant factors. In his contribution [19], examine the quality of an estimate through the application of expertise and experience with the help of the knowledge-based assessment model.

Also [20] presented result of a research effort that developed an estimate scoring model to measure the impact of four determinants on estimate accuracy.

- Who was involve in preparing the estimate,
- How the estimate was prepared,
- What was known about the project and

- Other factors considered while preparing the estimate.

While the result of [21] model enables estimators and business managers to objectively evaluate the accuracy of early estimates.

In their research [22] examined and added to the qualitative exploration of Value Management by investigating the attitudes and experience of value management facilitators within UK cost consultancies. While [23] proposed Principal Items Ratio Estimating Method PIREM, which integrates several existing conceptual estimating methods including parametric estimating, ratios estimating, and cost significant model with advanced nonlinear mapping techniques, and adopts a scheme that separates unit prices with the quantities of a cost item.

Also [24] described the development of linear / multiple regression models to predict the construction cost of buildings. The study of [25] attempted to identify the critical factors for effective estimation at various stages of typical construction projects and developed a theoretical framework that identifies the critical factors for effective cost estimation during each phase of a conventional construction project.

2.3 Factors Affecting Choice of Cost Estimation Model

Traditional building construction process follows design-bid-build phases. The cost estimation model applicable to these phases differs with progression in the level of detail for each phase. Members of the project team need and use cost estimation for different purposes. The owner wants to know the probable profit for projected capital outlay, and seek rapid estimate of the roughest cost. The designer needs the cost estimation to determine which schematic design solution best meets the client brief. And the contractor needs more detailed and reliable cost estimation in order to determine the tender price and manage project cash flow. Here, builder's quantities are measured and described from the builder's view point, not in accordance with SMM7 rules.

2.3.1 Computer Aided Building Cost Estimation Model

One of the computer-aided cost estimation systems used in schematic design phase is the integrated CAD and cost estimation packages which have graphical user interfaces for design and drawing working together with cost estimation.

The BMBS software provide some building cost analysis and two different building cost estimation model, based on traditional cost models, with one modified for Turkish construction sector[26].

The cost estimation model based on functional element is one the main modules of the software developed within the framework of the research project. The model is made for building cost estimation in the feasibility and schematic design phase using historic data of similar project.

It encompasses fives steps starting with entering the project data; then quantity entry of each functional element group; setting the average unit price of functional element group; estimating the total building cost and finally to revision of the total building cost.

The user can modify the project data to enlarge or narrow down the query range of the similar project stored in the database. Alternatively the user can save project data as in the first trial and make some modification on the composite element alternatives to move around the limits of the project budget. The software has the flexibility to create numerous alternatives among the existing composite element groups.

It is well known fact that up-to-date and reliable databases and information systems that support estimation are needed to make accurate cost estimation for different phases of the building construction process.

Cost estimation system must be simple, reliable, flexible and convenient to the nature of the application area. Even where only the total construction area and number of storey of the project is known, the user of the software can estimate approximate total building cost.

The average quantities of the functional element groups queried among the similar projects in the data base are used for budgeting. If user has sketches of the project, he can estimate total building cost easily as he measures the quantities of the functional element in each group on the project.

Furthermore, the user can select and decide which building materials to be used in the project, modify them or create numerous new composite element alternatives. Therefore the model allows the user to make cost planning studies.

As the user analyzes the total cost per m^2 of each functional element group, he has feedback even if the budget cost is overrun or not.

2.3.1.1 Model-Based Estimating

From the foregoing, building information models (BIM) can be used to accurately generate quantity takeoffs and assist in the creation of cost estimates throughout the lifecycle of the project. Thus model-based estimation enables the project team to see the cost effect of their design decisions and proposed changes during all phases of project. This feedback support better design decision making and help to curb excessive budget overrun arising from proposed modification.

Quantity takeoffs from a BIM models enable project teams to quickly generate cost estimates to assist in decision-making and provide cost information about alternatives to owners early in the design phase and throughout the project lifecycle.

The BIM model is integrated with cost information from an estimating database; and this approach has proven to be quicker and reduces the possibility for errors and omissions. It can also reduce quantity takeoff time and allow estimators to focus on high value activities, such as identifying construction assembles, generating pricing and factoring risks. The advantages of setting up a model-based estimating workflow far outweigh the upfront time and effort required to enable the process. It is leaner and smarter approach, because it automates the time consuming task of quantity takeoff, quickly provide cost feedback, and allows project team to focus on critical design and planning issue [27].

2.3.1.2 Cost Feedback

Cost feedback is most beneficial in the early design stages of a project, when design decision have the greatest impact on the eventual project cost. At preliminary cost check, it helps to confirm that the evolving design is on track and evaluate the cost impact of proposed design enhancements.

At detailed design and modeling of construction detail, BIM model is used to compute very detailed cost estimate that factor in the planned construction process and consider the labour, material, equipment and subcontractor costs for all building elements. Thus as the design evolves and more details are specified, the cost estimates grow more and more precise. The relevance of this cost feedback [27] includes;

- To compare cost plans to original project budget at all times,
- Enable stakeholders see the evolving changes and decide whether to adjust scope,
- Identify and focus on design decisions that have the largest impact on project cost,
- Evaluate the cost impact of proposed design enhancements and what-if-scenarios,
- Compare the impact of using sustainable design strategy in terms of installation time, cost, and projected energy savings,
- Focus estimating effort on maximizing value.
- Concentrate estimating effort on identified building elements that drive the project total cost i.e. place greater effort on part of project that have high risk value and variability, rather than subcontracted parts with fixed price.

With this successive estimating approach, the project team focuses efforts and attention on items that have the greatest potential cost impact.

2.3.1.3 Target Value Design

Notwithstanding the inherent benefits of focusing on designed elements that constitute primary cost drivers i.e. using cost estimate to drive design, emphasis should switch to ensuring that target cost for a project should never be exceeded. This is the object of Target Value Design {TVD} as a lean construction strategy. Here target cost dictates what gets design within approved budget.

2.4 Conceptual Estimating

Conceptual cost estimating is synonymous with approximate cost estimation and is the method of forecasting of project cost with insignificant design information and incomplete scope definition and using the result to determine feasibility, screen project alternatives and make important project decision go / no go and the appropriation of funds [28, 29 and 30]. Usually the evolved estimate must be adjusted for dissimilarity with proposed project specification, time, location and size.

2.4.1 Parametric Cost Estimate

The parametric model uses historic data as the basis of the model's predictive features

The output of parametric models include cost of major phases, duration of project major phases, total project cost and resource requirements.

Parametric model for construction would use such input data as: - project type, frame material, exterior material, ground condition, desired floor space and roof type.

Then using the general relationships developed between these input and output variables, the model provides an estimate of some or all of the output variables. The output variables include cost of design process, cost of the structure, size of major equipment, and optimum size of construction crew, size of parking lot, and duration of construction, or equipment installation and overall project duration.

Parametric models use different statistically derived algorithms, which in turn use different set of input and output data in calculating the output variables.

Based on the input variables, the models are regularly evaluated, validated, calibrated and customized for accuracy and appropriateness and used to establish preliminary project budget.

2.5 Substructure of Building.

Building structure comprises of substructure and superstructure. The substructure transmits self load and load of the superstructure above and life load to the foundation. Hence the soil and foundation being the lowest part of the structure should be strong enough to support these load [31]. Foundation is design to serve the following purposes;

- To distribute loads of structure over a large bearing area so as to bring intensity of loading within the safe bearing capacity of the underlying soil.
- To load the bearing surface at a uniform rate so as to prevent unequal settlement.
- To prevent the lateral movement of the supporting materials
- To secure the level and firm bed for building operation.
- To increase the stability of the structure as a whole.

Factors affecting the selection of foundation include; - types and intensity of loads acting on various part of the structure viz; dead load, life load, wind load, snow load etc. and soil type and its bearing capacity. Hence foundation design must reflect the total anticipated loads and bearing capacity of the soil. Excessive load that deforms the soil, move soil, and create change in volume, can cause settlement.

Shallow foundation or deep foundation may be used depending on anticipated loads and ground conditions.

Shallow foundations [31] are those near the finished ground surface with depth less than width of footing by {or 3m] and include spread/footings, pad/isolated, strip foundations or their combinations and raft foundation.

Deep foundation are those whose base are founded deeply below finished ground surface {depth >3m} and are not affected by surface conditions. These include; pile, well and caisson foundations. They transfer load to deeper soil or rock of high bearing capacity. They often resist vertical, lateral and uplift load. Pile foundation is prescribed when: - the soil is very soft and solid bed is not available at reasonable depth to keep the bearing power within safe limits; provision of pad and raft foundations are very expensive; structures carry heavy concentrated loads; buildings located along sea-shore or river bed.

Often details of these foundation types and designs are not available to the estimator at scheme design stage to support his cost estimate.

3.0 Research Methodology

The research is design to model the relationship between the architectural and structural design variables for quick estimation of cost of concrete in column bases of residential duplexes. It centered on calculating the approximate quantities of concrete in column bases to which omnibus rate will be applied to deduce cost of concrete.

The research carried out incisive literature search and issued questions and interviewed practicing quantity surveyors and construction cost estimators to elicit information on how they handled relationship between architectural design and structural design variables in cost estimation of substructure of residential duplexes at sketch design. It selected the floor area, the number of column bases, the volume of concrete in the column bases, trench girth and block work girth as substructure variables for the analysis.

Architectural and structural plan and section drawings of 30 executed residential duplexes with 225mm sand crete block walls were purposively obtained from the practitioners and approximate quantities in applicable unit were collated for the variables in each duplex project { see table 1}. Mean values of these item’s quantities were calculated. Regression analysis was used to investigate the relationships and craft mathematical model between the variables to measure particularly the quantitative effect of varying floor area, trench girth and block wall girth on cost of concrete in column base {see models 1-5}.

This was done for each of the independent/predictive variables using linear regression and for two or more independent/explanatory variables using multiple regressions {model 5}. The statistical validity/significance of the estimated model was then established by comparison with results from pre-test of substructure variables of three different residential buildings. The data are presented as shown below;

4.0 Data Presentation and Analysis

Table 1 Measured Quantities of Selected Substructure Variables.

Project ID	FA	NrCB	VCb	Tgth	Bgth	Bgth - Tgth	Cb length
1	210.94	28	10.33	88.34	152.30	6416	38.30
2	214.23	27	9.78	94.49	129.52	35.03	34.50
3	262.78	33	10.27	109.75	153.00	43.05	42.30
4	188.31	23	8.85	92.62	132..99	40.37	37.55
5	210.18	29	8.96	108.90	148.43	39.53	38.00
6	278.83	20	9.06	107.35	154.80	47.45	38.40
7	296.08	35	15.77	113.14	176.87	63.46	56.40
8	265..55	25	9.86	107.19	149.85	42.66	43.92
9	157.05	21	8.11	72.89	108.00	35.11	34.78
10	302.86	31	16.55	141.19	198.06	56.87	55.58
11	260.82	37	11.10	124.35	171.71	47.36.	46.50
12	129.08	22	10.44	67.62	103.64	36.02	35.60
13	121.75	27	9.78	107.21	121.75	14.54	13.00
14	178.44	30	8.90	92.91	129.97	37.06	35.78
15	298.37	25	17.01	140.78	178.58	37.08	36.01
16	103.61	15	8.10	50.41	73.99	23.58	22.50
17	236.05	28	8.40	193.15	231.85	38.70	36.59
18	239.69	30	10.61	92.23	134.77	42.54	41.04
19	319.32	35	15.61	126.00	181.44	52.44	46.12
20	447.12	51	19.12	193.02	272.09	79.07	71.58
21	218.99	36	15.66	117.11	175.41	58.30	57.50
22	213.24	27	11.66	83.08	129.80	46.72	40.20
23	254.56	35	12.10	126.70	175.80	49.10	47.70
24	184.32	25	9.05	107.47	161.40	54.40	53.01
25	331.47	37	16.73	131.07	176.59	45.52	44.06
26	125.76	25	10.58	75.87	120.15	44.28	42.79
27	224.80	32	11.72	191.50	241.90	50.40	49.01
28	230.41	30	9.14	100.62	139.93	39.31.	37.45
29	155.90	20	8.03	81.49	113.37	31.88	30.01
30	215.18	27	8.90	111.37	152.13	40.76	38.96

Sources; Author's Survey (2014)

Regression Models 1 – 5

As mentioned the four linear regressions and one multiple regression models utilized for the study are as below. Multiple regression model was introduce to allow the combined effects of the substructure variables to be estimated viz: vol. of concrete in column base as a function of floor area.

Vcb = mFa + e……………………………………………………………..Model 1

Volume of concrete in column base as a function of block work girth

Vcb = mBgth + e……………………………………………………………Model 2

Number of column base as a function of block work girth

Nrcb = mBgth + e…………………………………………………………Model 3

Number of column bases as a function of Floor area of building

Nrcb = mFA + e …………………..……………………………………… Model 4

Volume of concrete in column base as a combined function of floor area / block work girth.

Vcb = m_1FA + m_2Bgth + e ………………….………………..……………………Model 5

Key Vcb = Volume of concrete in column base

Nrcb = Number of column base

FA = Floor base area.

Bgth = Block work girth

Tgth = Trench girth.

M denote the gradient and e (regression constant) or intercept of the linear equation

M_1 and M_2 denote the coefficient or the degree of contribution per unit change in floor area and block work girth respectively.

Statistical package for science students SPSS2O was used to run a descriptive analysis on the presented set of data (see table 2).

And the percentage of the block work centre line girth that would be taken up by the column base length, as well as the percentage of the block work girth that would be adjusted to get the trench girth were established:

Percentage of block work girth (Bgth) taken up by column base Length (cbl)

$$= \frac{\text{mean Cbl}}{\text{mean Bgth}} \times 100\% = \frac{41.50}{156.34} \times 100\%$$

$$=26.54\%$$

Percentage of the block work Girth (Bgth) adjusted to get The trench girth (tgth)

$$= \frac{\text{mean (Bgth – Tgth)}}{\text{mean Bgth}} \times 100\% = \frac{44.58}{156.34} \times 100\%$$

$$=28.52\%$$

Table 2: SPss 20 Variable Descriptive Statistics Analysis

	N	SUM	Mean		Std Deviation
	Statistic	Statistic	Statistic	Std Error	Statistic
Cbl	30	1245.14	41.5047	1.99514	10.92783
FA	30	6875.69	229.1897	13.29784	72.83525
Nrcb	30	866.00	28.8667	1.26376	6.92190
Vcb	30	340.18	11.3393	.58428	3.20023
Tgth	30	3350.09	111.6697	6.31532	34.59043
Bgth	30	4690.29	156.3430	7.65033	41.90258
Bgth – Tgth	30	1337.47	44.5823	2.27289	12.44911
Valid N (List wise)	30				

Source Author's survey (2014)

From the analysis the estimated / predicted regression models are:-

The First Linear Regression Model VCb = mFA + e

REGRESSION STATISTICS		**VARIABLES**	**COEFF.**	**P-VALUE**
No. of observation	= 30	Floor area	0.033	0.000
R	= 0.754			
R square	= 0.569			
Adjusted R square	= 0.554			
F	= 36.995			
		Constant	**3.742**	**0.008**

The predicted equation is:
VCb = MFA + e = 3.742 + 0.033FA………………………………………… Model 1

Similarly Predicted Equations for the other models are:

Linear Regression Model Vcb = mBgth + e =
Vcb = mBgth + e = 3.985 + 0.047 Bgth……………………………………Model 2.
Correlation R = 0.616
Coefficient of determination R^2 = 0.379
Regression Coefficient = 0.047
Regression Constant (R) = 3.985

Linear Regression Model NrCb = mBgth + e =
NrCb = mBgth + e = 9.703 + 0.123 Bgth ……………………………………….Model 3
Correlation R = 0.742
Coefficient of determination R^2 = 0.551
Regression coefficient = 0.123
Regression constant (R) = 9.703

Linear Regression model NrCb = mFA + e =
NrCb = mFA + e =12.331 + 0.072FA………………………………………… model 4
Correlation (R) = 0.759
Coefficient of determination (R^2) = 0.576
Regression Coefficient = 0.072
Regression Constant (R) = 12.331

Multiple Regression Model VCb = M_1FA + M_2Bgth + e.
VCb = M_1FA + M_2 Bgth + e = 3.426 + 0.031FA + 0.006Bgth ……………… Model 5
Correlation (R) = 0.756
Coefficient of determination (R^2) = 0/572
Regression Coefficient of block work girth = 0.006
Regression Coefficient of floor area = 0.031
Regression Constant (R) = 3.426

5. Analysis, Findings and Discussion

5.1 Model Validation
The predicted models were validated using analyzed result from architectural drawings of three duplexes different from the set of drawings used to develop the models.

The result and variable descriptive statistics of the pretest drawings did not vary significantly from that of the predicted models.

For linear regression model of volume of concrete in column base as a function of floor area, the coefficient of correlation R 0.754 and coefficient of determination R^2 0..569 indicate very high relationship between concrete in column base and the floor area of a duplex. It depicts that only 43.10% (1 – 0.569) of change in column base concrete is not explained by change in floor area. The predicted equation is statistically significant hence estimated volume of concrete in column base using this model with be realistic.

For linear regression model of volume of concrete in column base as a function of block work girth, coefficient of correlation R (0.616) and determination R2 (0.379) show good relationship, but indicates that about 62.1% (1-0.379) of changes in volume of concrete in column base are not explained by change in block work girth. The equation though statistically significant does not guarantee accuracy of the estimated volume of concrete using the model.

For linear regression model of number of column base as a function of block work girth, the coefficient of correlation R (0.742) and determination R^2 (0/551) show high relationship and good possibility that number of column bases would increase with increase in block work girth. The model is statistically significant and number of column base estimated using the model will be realistic.

For linear regression model of number of column base as a function of the floor area, the coefficient of correlation R (0.759) and determination R^2 (0.576) depict very high relationship, with changes in floor area reasonably accounting for changes in number of column base, leaving only 42.4% explained by other variables not included in the model.

For the multiple regression model of volume of concrete in column base as a function floor area and block work girth, the coefficient of correlation R (0.756) and determination R^2 (0.572), show very high level of relationship between volume of concrete in column base and combined effects of floor area and block work girth. It depicts that above average changes in volume of concrete in column base is explained by joined impact of changes in floor area and block work girth. The equation is statistically significant and the estimated volume of concrete will be realistic.

6.0 Conclusion

This study attempts to model the relationship between design variables in the substructure of duplexes using linear and multiple regression techniques. The models were developed based on architectural and structural drawings of thirty residential duplexes collected from construction and cost professionals and validated using data of three duplexes.

These models are very useful, especially in its simplicity and ability to be handled by calculators or a simple computer programme. It has a good benefit in estimating substructural cost at early stages of residential building since the information needed could be gotten at the sketch design.

The aim of this study was achieved by the generation of four regression models and one multiple regression model. The models use the floor areas, the trench girth, the block work girth to determine the number of column base and the volume of concrete in the column base.

The coefficient of determination, R^2 for the first developed model (model 1) is 0.569, which indicates that the relationship between the independent and dependent variables of the developed model is good and the predicted values from this forecast model fit with the real life data.

The coefficient of determination, R^2 for the second developed model (model 2) is 0.375 which indicate that there is little relationship between the independent and dependent variables, therefore, the predicted values from a forecast model might not always fit the real life data.

The third model developed (model 3) is a model of the number of column bases as a function of the block work girth. Its coefficient of determination R^2 is 0.551 which indicates a moderate degree of fitness of predicted model into the real life data.

The fourth model developed (model 4) is also a model of number of column base as a function of floor area and its coefficient of determination R^2 0.576 indicate also a moderate degree of fitness of predicted model into the real life data.

The fifth model developed (model 5) is developed from multiple regression analysis, a model of the volume of concrete in column base as a function of the floor area and block work girth and its coefficient of determination R^2 0.572 indicates also a high degree of fitness of predicted model into the real life data.

Therefore, to determine the volume of concrete in column base, the user of the model should;

- First determine the floor area (FA) of the building and the block work centre line girth (Bgth)
- Then slot the values of FA and Bgth in the model to determine the volume of concrete in the column base.

These steps should also be followed by user of the other models developed in the course of this research work. Also this research establishes that block work girth should not be used alone to determine the approximate quantities of the volume of concrete in column base.

Finally, the research highlighted the proportion of block work girth taken up by the column base length as 26.54%, while the percentage of the block work girth that would be adjusted to get the trench girth is 28.50%.

7.0 Recommendations

This research presents approximate quantities model that attempts to improve on the existing approximate quantity model by providing further insight into the relationship between the volume of concrete in the column base and the various predictor variables which are the floor area and the block work girth. The study recommends from the foregoing findings and conclusion that;

- Block work girth should not be used alone to estimate the volume of concrete in column base because it has proved not to be a good predictor of column base concrete.
- Accurate estimate of floor area and block work girth should be applied in the established model for determination of approximate quantity and cost of concrete in column bases.
- The approximate quantity model is adequate and fit to be used for the forecast of the volume of concrete in column base at sketch design stage when there is no detailed plan.

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