Application of BIM on Quantity Estimate for Reinforced Concrete and Formwork

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Abstract: The focus of this study is on the accuracy in quantity estimates made by BIM for materials needed during construction. BIM-Revit Architecture 2014 is utilized to establish the information for an actual case to conduct estimates for the amount of reinforced concrete and formwork needed. The actual case is with a total construction area of 5,438 square meters and a total floor area of 31,623 square meters. The building commenced in December 2012 and the major structure has been completed in 2014. It is a RC structure with 4 stories underground, 12 stories above and 3 roof floors. The result shows that both of the quantity estimates of reinforced concrete and formwork are higher than that of actual use in the case. The estimate of reinforced concrete is higher than that of actual use by 2.18%, while the estimate of formwork is higher than that of the actual use by 13.04%. The results indicate that the estimate of reinforced concrete made by BIM has high accuracy, but the accuracy of the formwork estimate still needs improvement.

Keywords: BIM, Reinforced Concrete, Formwork, Quantity Estimate

I. INTRODUCTION

The life cycle of a construction project is quite lengthy. It encompasses planning, design, construction, operation, maintenance and demolition. For a construction company, the success of a project relies on comprehensive and complete information and involves making the right decision at the right time, particularly strategies related to effective control over costs and schedule while maintaining the quality demanded by clients. Technological advances brought increasing complexity to building styles and the construction process, creating noticeable impacts of material use on construction costs and schedule. Insufficient amount of material would cause project delay while too much leads to waste. Idle materials also pose indirect effects due to deteriorating quality. These factors highlight the importance of precise estimate and control of construction materials. Formwork and RC are two essential construction materials. In general, structural construction accounts for 30.96 to 39.71% of the total costs. Among which, 7.16 to 8.45% is for formwork and 11.24 to 17.91% is for RC construction (Chen, 2011). Both need to be closely monitored. Conventionally, material estimate relies on manual calculation, which is time consuming and prone to human errors. Building Information Modeling (BIM), which emerged in recent years, can now be applied and integrated into the building life cycle. With its parametric quality and huge data bank, BIM has tremendous advantages over the conventional 2D drawings. It is easier to control building information such as the area, volume, material, quantity and costs during the design stage. Therefore, the purpose of this study is to take advantage of the parametric quality of BIM to estimate the formwork and RC quantity, and evaluates its accuracy by comparing them with the actual amount of materials used.

II. BIM APPLICATIONS

BIM can be used to improve the performance and productivity of an asset's design, construction, operation and maintenance process. The benefits of implementing BIM include: a reduction in construction costs, improved quality of design information, integration of project systems, data and teams, a reduced propensity for change orders, improved interoperability, and whole life-cycle asset management (Love, 2014). Recently, there are some discussions over quantity evaluation of BIM. For examples, Chen (2011) verified the quantities of concrete and steel taken off from the BIM models of a 12-story reinforced concrete building by comparison with traditional estimation of the same project. Fu (2011) used BIM to evaluate the building materials. Guo (2012) applied UNIFORMAT II to BIM and evaluated reinforced concrete in residential buildings. Moreover, Atul Porwal et al. (2012) proposed a model to analyze reinforced concrete structure with one-dimensional (1D) cutting waste-optimization technique integrated with BIM. The proposed approach was validated with a two-story reinforced concrete structure, and the results indicated a high potential for budgetary savings. Cheng (2012) compares the differences in quantity estimates made by BIM and a senior engineer using conventional method for materials needed during construction. The results indicate that estimates made by BIM have high accuracy. Monteiro et al. (2013) explores the subject by presenting a case study that surveys BIM input/output dynamics for quantity takeoff, examining model behavior when constrained by existing specifications for quantity takeoff, and detailing modeling guidelines that allow the user to extract quantities according to current specifications.

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Ⅲ. Background Information

The actual case – CEO corporate headquarter (as shown in Fig. 1,2), which is with a total construction area of 5,438 square meters and a total floor area of 31,623 square meters, is located in Linkou, New Taipei City. The building commenced in December 2012 and is scheduled to be completed in May 2016. The main structure was completed in 2014. It is a RC structure with 4 stories underground, 12 stories above and 3 roof floors. The construction budget is about NTD $1,200,000,000. The floor plan and elevation are shown in Fig. 3 and 4, respectively.

FIGURE 1 MODEL SHOWING EXTERIOR OF CEO BUILDING

FIGURE 2 CONSTRUCTION OF B2F

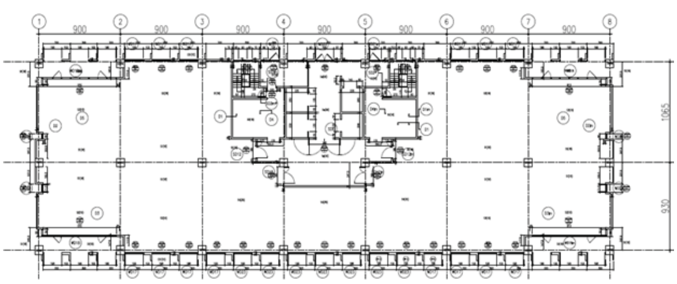

FIGURE 3 FLOOR PLAN

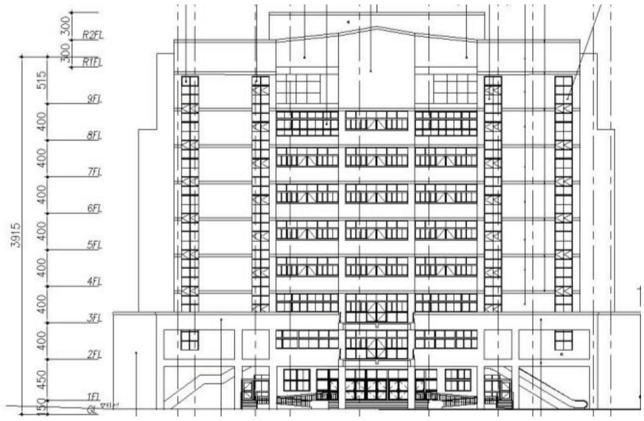

FIGURE 4 ELEVATION

Ⅳ. REVIT MODEL OF CEO BUILDING

Prior to establishing the BIM database and drawings, data analysis must be conducted according to the construction drawings. Work Breakdown Structure (WBS) is utilized to deconstruct the cases into individual components with different information added according to the different characteristics. After analyzing the 2D construction drawings for this case, the 3D models are constructed using Revit Architecture 2014 based on the different components. Fig. 5 shows the 3D model for the case.

FIGURE 5 3D MODEL FOR THE CEO BUILDING

Ⅴ. Formwork Quantity Calculation

By using "paint" in Revit, formwork quantity is calculated by simulating the total area of formwork on the surface of the structure. The system automatically generates an itemized table showing quantity estimate. The deduction of overlapping areas among columns, beams, walls and floors is the most complicated in formwork estimate, which makes the "connection" extension in Revit especially crucial. Applying the connection extension to the beams would deduct the areas that overlap the columns, walls and floors. The result is significant for formwork estimate with the "paint" function as well as the RC estimate. Table 1 shows the comparison between the estimate and the actual quantity used, and the total error is

13.04%. The itemized table for beams generated in Revit is exported to Excel. The detailed information is shown in Tables I and Ⅱ in the Appendix.

TABLE 1 FORMWORK QUANTITY COMPARISON RESULT

Estimate by Revit (m²)	Actual Quantity (m²)	Error (m²)	Percentage Error (%)
104693.1	92617.7	12075.40	13.04%

Ⅵ. Calculation of RC Quantity

RC calculation is relatively simple compared to that of the formwork. Revit is able to produce an itemized table showing RC quantity. However, the industry practice has been to calculate RC quantity by the number of floors. To compare with the actual use, some of the parameters must be set to create consistent format prior to producing the itemized output. Table 2 shows the comparison with actual usage and indicates a total error of 2.18%. The detailed information is shown in Tables Ⅲ and Ⅳ in the appendix.

TABLE 2 RC QUANTITY COMPARISON RESULT

Estimate by Revit (m^3)	Actual Quantity (m^3)	Error (m^3)	Percentage Error (%)
21867.24	21400	467.24	2.18%

Ⅶ Conclusion

This study explores the differences between quantity estimates conducted with Revit 2014 and the actual quantity used. RC quantity estimate produced in Revit is 21,867.24 m^3 while the actual quantity used is 21,400 m^3. The comparison indicates a difference of 467.24 m^3 and the percentage error of 2.18%. The formwork estimate made in Revit is 104,693.1 m^2 while the actual quantity is 92,617.7 m^2. The percentage error is 13.04%. Estimation can be classified into conceptual estimate, semi-detailed estimate and detailed estimate with margins of error of ±25%, ±15% and ±5%, respectively (Chong, 2010). By this definition, the RC estimate produced in Revit is considered detailed estimate while formwork estimate is classified as semi-detailed estimate.

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APPENDIX

TABLE I ITEMIZED TABLE OF FORMWORK QUANTITY

Floor	Columns (m²)	Beams (m²)	Floor Slabs (m²)	Walls (m²)	Other (m²)	Subtotal (m²)
B4F (including water tank, floor joist and base plate)	891.9	6543.08	3914.89	1232.61	32.39	12614.87
B3F	891.9	685.29	3525.67	1232.61	66.88	6402.35
B2F	884.59	762.25	3494.96	1232.61	93.42	6467.83
B1F	1258.74	3444.55	3439.05	1676.52	152.52	9971.38
F1	584.65	1686.48	3008.21	2632.05	59.84	7971.23
F2	466.46	2729.84	1448.65	2129.99	58.54	6833.48
F3	384.48	1329.8	1007.46	1603.11	59.17	4384.02
F4	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F5	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F6	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F7	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F8	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F9	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F10	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F11	384.48	1329.8	2016.18	1603.11	59.17	5392.74
F12	401.76	7.55	21.14	1692.28	69.37	2192.1
R1F	114.8	322.41	995.26	859.92	52.78	2345.17
R2F	96.62	228.46	292.35	499.93	22.44	1139.8
R3F	96.14	390.79	113.1	401.73	0	1001.76
PRF	0	0	156.61	70.58	0	227.19
Total (m²)						104693.1

TABLE Ⅱ FORMWORK QUANTITY COMPARISON

Floor	Estimate by Revit (m²)	Actual Quantity (m²)	Error (m²)	Percentage Error (%)
B4F (including water tank, floor joist and base plate)	12614.87	6323.9	6290.97	99.48%
B3F	6402.35	6453.32	-50.97	-0.79%
B2F	6467.83	6542.39	-74.56	-1.14%
B1F	9971.38	6635.63	3335.75	50.27%
1F	7971.23	9500	-1528.77	-16.09%
2F	6833.48	5513.67	1319.81	23.94%
3F	4384.02	4161.43	222.59	5.35%
4F	5392.74	4161.43	1231.31	29.59%
5F	5392.74	4161.43	1231.31	29.59%
6F	5392.74	4161.43	1231.31	29.59%
7F	5392.74	4161.43	1231.31	29.59%
8F	5392.74	4161.43	1231.31	29.59%
9F	5392.74	4161.43	1231.31	29.59%
10F	5392.74	4161.43	1231.31	29.59%
11F	5392.74	4161.43	1231.31	29.59%
12F	2192.1	4161.43	-1969.33	-47.32%
R1F	2345.17	4690.85	-2345.68	-50.01%
R2F	1139.8	2278.72	-1138.92	-49.98%
R3F	1001.76	1544.67	-542.91	-35.15%
PRF	227.19	1520.25	-1293.06	-85.06%
Total (m²)	104693.1	92617.7	12075.40	13.04%

TABLE Ⅲ ITEMIZED TABLE FOR RC QUANTITY

Floor	Columns (m³)	Beams (m³)	Floor Slabs (m³)	Walls (m³)	Subtotal (m³)
B4F (including water tank, floor joist and base plate)	164.98	2027.83	3063.16	429.66	5685.63
B3F	164.97	71.1	618.98	429.66	1284.71
B2F	163.33	98.78	618.19	429.64	1309.94
B1F	256.83	491.92	1115.49	573.71	2437.95
F1	116.69	221.02	704.98	338.68	1381.37
F2	97.74	359.67	252.86	165.99	876.26
F3	77.12	188.33	250.47	124.54	640.46
F4	77.12	188.33	501.17	124.54	891.16
F5	77.12	188.33	501.17	124.54	891.16
F6	77.12	188.33	501.17	124.54	891.16
F7	77.12	188.33	501.17	124.54	891.16
F8	77.12	188.33	501.17	124.54	891.16
F9	77.12	188.33	501.17	124.54	891.16
F10	77.12	188.33	501.17	124.54	891.16
F11	77.12	188.33	501.17	124.54	891.16
F12	81	0.58	250.7	132.2	464.48
R1F	22.15	38.51	248.27	68.76	377.69
R2F	18.17	30.74	42.12	38.69	129.72
R3F	18.07	53.65	16.96	32.28	120.96
PRF	0	0	23.51	5.28	28.79
Total (m^3)					21867.24

TABLE Ⅳ RC QUANTITY COMPARISON

Floor	Estimate by Revit (m^3)	Actual Quantity (m^3)	Error (m^3)	Percentage Error (%)
B4F (including water tank, floor joist and base plate)	5685.63	5234.5	451.13	8.62%
B3F	1284.71	2229	-944.29	-42.36%
B2F	1309.94	2179.5	-869.56	-39.90%
B1F	2437.95	2151.5	286.45	13.31%
1F	1381.37	2363.5	-982.13	-41.55%
2F	876.26	570.5	305.76	53.60%
3F	640.46	601.5	38.96	6.48%
4F	891.16	563	328.16	58.29%
5F	891.16	545	346.16	63.52%
6F	891.16	545	346.16	63.52%
7F	891.16	576	315.16	54.72%
8F	891.16	570	321.16	56.34%
9F	891.16	558	333.16	59.71%
10F	891.16	566	325.16	57.45%
11F	891.16	567	324.16	57.17%
12F	464.48	574.5	-110.02	-19.15%
R1F	377.69	644.5	-266.81	-41.40%
R2F	129.72	109.5	20.22	18.47%
R3F	120.96	103	17.96	17.44%
PRF	28.79	148.5	-119.71	-80.61%
Total (m²)	21867.24	21400	467.24	2.18%