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COST MODEL FOR USING GLASS FIBRE REINFORCED GYPSUM SYSTEM (GFRG)

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ABSTRACT: *One of the mile stones for the success of construction projects is the project management triangle (time, quality and cost). During the past decade, a lot of construction systems have been developed to this triangle. GFRG system was one of these systems (for example that was established in Australia). Concerning quality aspect, GFRG system has fulfilled LEED certificate for construction materials, with respect to time aspect, it is superior to regular construction methods, when it is compared with traditional systems. As for cost, owner/ designer needs to calculate estimated direct cost for the GRFG panels and materials at the design phase, which will increase the economic value for these projects. This paper aims to study the GFRG system & design cost model to analyse direct cost for the system during the design phase.*

KEYWORDS: GFRG, Installation, Cost model, direct cost, cost analysis

INTRODUCTION

GFRG is the abbreviation for glass fibre reinforced gypsum. It is the name of a new building panel product, made essentially of gypsum plaster, reinforced with glass fibres, and is also known in the industry as Rapid wall. This product, suitable for rapid mass-scale building construction, was originally developed and used since 1990 in Australia. GFRG is of particular relevance to India, where there is a tremendous need for cost-effective mass-scale affordable housing, and where gypsum is abundantly available as an industrial by-product waste. The product is not only eco-friendly or green, but also resistant to water and fire.

The market price for this system is divided into two main aspects; cost & mark-up as shown in figure 1. Mark-up aspect is divided into contingency, which is mainly related to risk analysis & it differs with respect to site, owner & project. The other aspect is profit margin, which depends on market status & feasibility study for project. Cost aspect is divided into two phases which are the direct cost & indirect cost. Mark up & indirect cost aspects can't be analysed in this research as they are project oriented aspects. The paper aims to analyse the direct cost aspect for GFRG system & design cost model during the design phase; to achieve optimization level for system.

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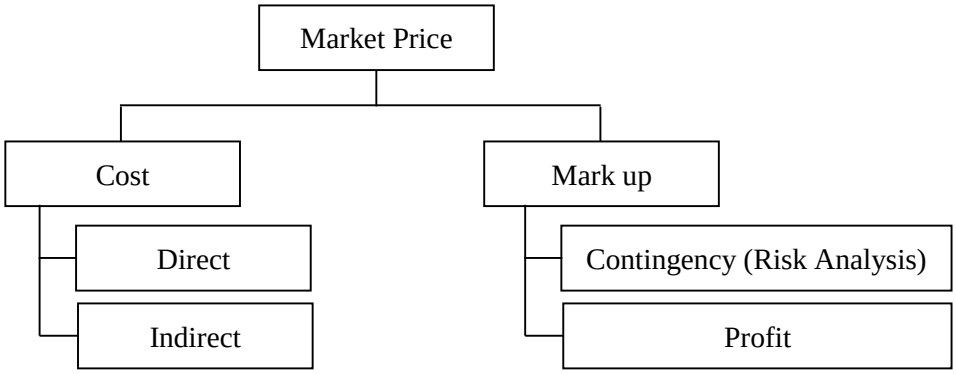

Figure 1: Market price for GFRG system

Source: Professional program for Project Management, American University in Cairo, Project Planning Course, Lectures, 2009

LITERATURE REVIEW

Glass Fibre Reinforced Gypsum definitions

GFRG panels are presently manufactured to a thickness of 124 mm, a length of 12m and a height of 3m, under carefully controlled conditions. The panel can be cut to required size. Although its main application is in the construction of walls, it can also be used in floor and roof slabs in combination with reinforced concrete. The panel contains cavities that may be filled with concrete and reinforced with steel bars to impart additional strength and provide ductility. The panels may be unfilled, partially filled or fully filled with reinforced concrete as per the structural requirement.

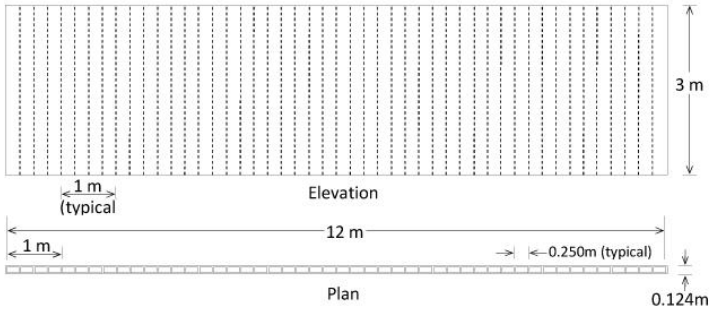

Figure 2: Typical Cross Section of GFRG Panel

Source: GFRG Building Structural Design Manual

GFRG building panels are presently manufactured as Rapid wall, for the typical dimensions and material properties described in the manual. Typical dimensions of a GFRG building panel are 12.0m*3.0m* 0.124 m, as shown in Figure 2. Each 1.0 m segment of the panel contains four ‘cells’. Each cell is 250 mm wide and 124 mm thick, containing a cavity 230mm*94 mm, as shown in Figure 3. The various cells are inter-connected by solid ‘ribs’ (20 mm thick) and ‘flanges’ (15 mm thick), comprising gypsum plaster, reinforced with 300 - 350 mm glass fibre roving, located randomly but centrally. The skin thickness is 15 mm and rib thickness is 20 mm.

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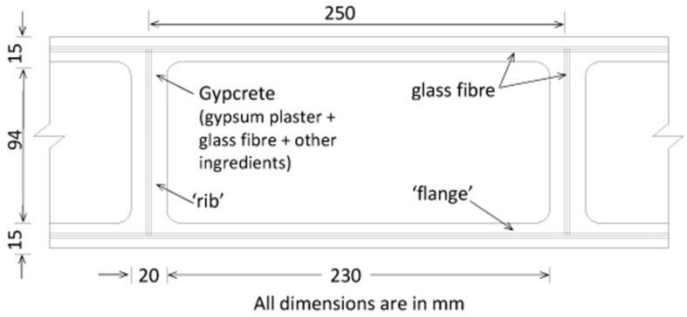

Figure 3: Enlarged View of a Typical Cell

Source: GFRG/Rapid wall building structural design manual

Glass Fibre Reinforced Gypsum uses

In typical multi-storeyed constructions involving the use of GFRG as load bearing structural walling, the connections between cross walls and with the foundations and floor/roof are achieved through reinforced concrete filling or R.C beams. All GFRG wall panels at the ground floor are to be erected over a network of RC plinth beams supported on suitable foundation as shown figure 4.

GFRG panel can also be used for intermediate floor slab/roof slab in combination with RC. The strength of GFRG slabs can be significantly enhanced by embedding reinforced concrete micro beams. For providing embedded micro beams, top flange of the respective cavity is cut and removed in such a way that minimum 25 mm flange on both end is protruded as shown in Figure5. RC concrete screed of minimum 50 mm thickness is provided above the GFRG floor panel & most likely thickness used is 80 mm. RC screed is reinforced with weld mesh of minimum size of 10 gauge 100 mm × 100 mm. This RC screed and micro beam act together as series of embedded beams. The thickness of the RC screed, reinforcement and interval of embedded RC micro beams depends on the span and intensity of imposed load. The connectivity between the horizontal tie beam, embedded RC micro beams, concrete screed and vertical rods in GFRG wall, and ensures perfect connection between floor/roof slab and walling system.

Figure 4: Erection of GFRG panels over plinth beam at site

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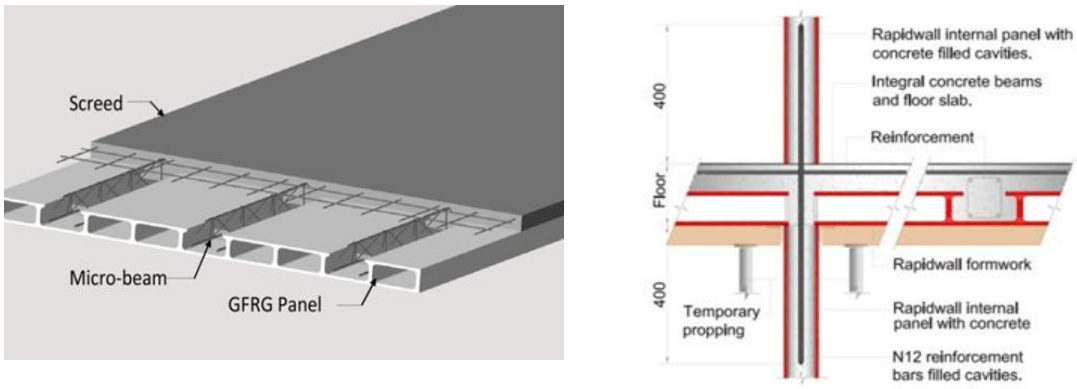

Figure 5: GFRG floor slab with micro beam and screed

Installation of Glass Fibre Reinforced Gypsum

GFRG installation system will be installed as the following steps:

1- Prior to delivery of the panels the surveyors establish and mark all main grid lines on the foundations or the concrete suspended floor onto which GFRG panel is to be positioned.

2- Using the Architectural layout drawings the erection crew marks out the wall positions in reference to these grid lines.

3- Holes are drilled in the concrete foundation, starter bars inserted and waterproof membrane applied.

4- Pre-cut GRFG panels are lifted by crane onto the prepared concrete floor or foundation.

5- Using GFRG lifting jaws, the pre-cut GFRG panels are decanted, one by one, from the stillage and placed into their final position, propped and screwed together.

6- Plumbing and electrical services are installed in the voids and if required, concrete is poured or insulation inserted into the cavities.

7- Post construction the GFRG panels are finished in a conventional manner.

8- Each panel has (A) and a (B) side. Normally the smoother (A) side is installed internally whereas the (B) side is used externally.

9- External renders or decorative facings can be added externally and internally the panels flushed and finished ready for primers.

METHODOLOGY

The research methodology is divided in two parts; theoretical aspect will discuss the building design using Glass Fibre Reinforced Gypsum panels according to design manual, installation manual, and system requirements. Practical aspect concerning cost of Glass Fibre Reinforced

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Gypsum during operation process, In addition to that, data was gathered from different projects using GFRG system concerning construction cost & installation procedures on site.

The cost analysis for Glass Fibre Reinforced Gypsum during construction process can be classified into three categories, cost per meter square of panel, cost per number of panels and cost with respect to building foot print & building built-up area as shown in figure 6.

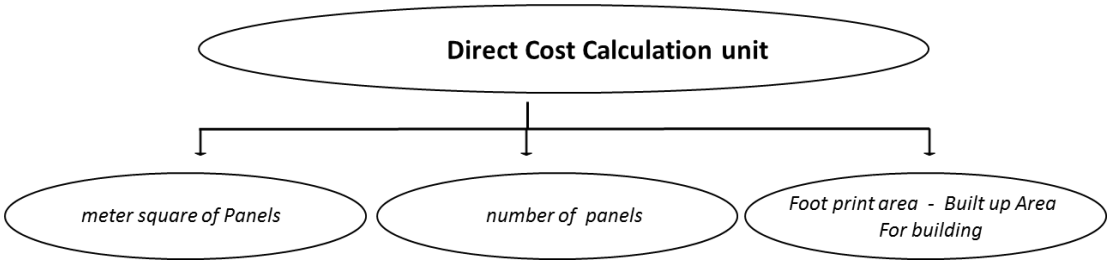

Figure 6: Direct cost calculation unit

Source: by Author

FINDINGS

Glass Fibre Reinforced Gypsum Direct cost analysis

Through practical process, direct cost was concluded to be divided into main 6 categories as shown in figure 7. The categories for the direct cost are GFRG panels, Panel accessories, Electric hand tools, Crane cost, labours cost & reinforced concrete cost.

GFRG panels are precast fabricated panels that will be installed on site, panel supplied cost is calculated by meter square. Panel accessories consist of studs (3 meters length for each unit) which are used to fix the panel with each other's, joint tab mesh (50 meters length roll) which treat the joints between panels & corner mesh (3 meters length for each unit) which treat joints between panels at corners. The cost of these accessories is calculated by unit.

Electric hand tools are the tools used for operation; fixation during construction of the panels on site, the cost for these tools is calculated by cost per hour. Crane cost consists of crane cost & crane driver cost. The cost for crane is calculated by cost per hour. Labour cost consists of engineer cost, technical man cost & manpower cost, the cost of labour is calculated by cost per hour. While Reinforced concrete cost consists of sub-structure which is the reinforced concrete for foundation system of building, super structure which is the reinforced concrete inside the cavity of GFRG vertical panels representing walls & GFRG horizontal panels representing slabs & micro-beams. The cost for reinforced concrete is calculated by cost per m3.

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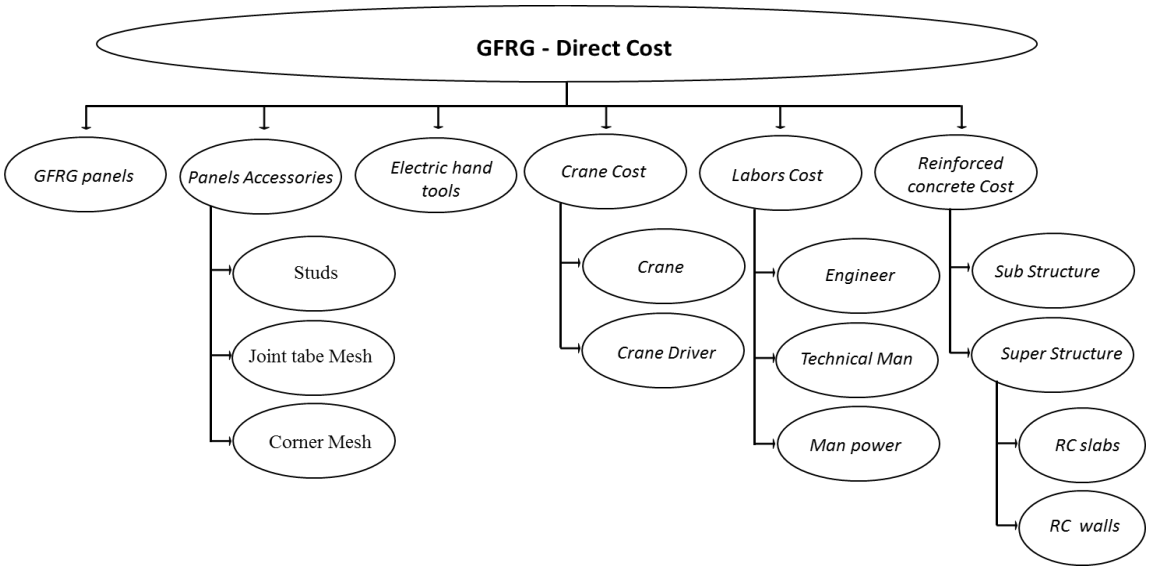

Figure 7: Direct cost analysis for GFRG system

Source: by Author

According to the cost analysis during operation phase for Glass Fibre Reinforced Gypsum on site, the following figure 8 shows the classification of direct cost with respect to calculation unit. GFRG panels & Panels accessories will be calculated with respect to meter square of GFRG panels. Electric hand tools, crane cost & Labours cost will be calculated with respect to number of GFRG panels. Reinforced concrete cost will be calculated with respect to foot print area & built-up area.

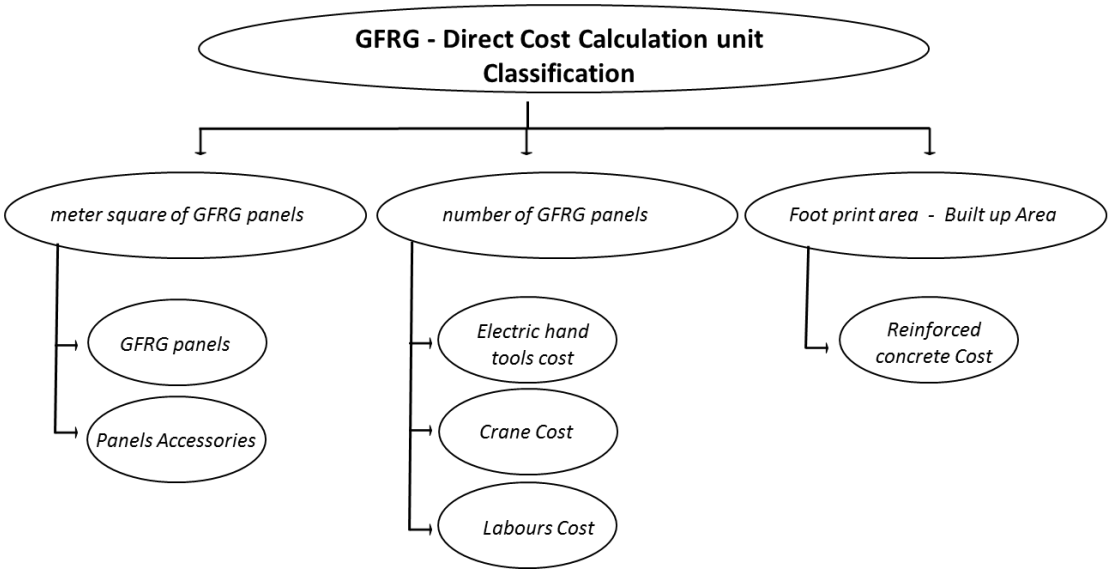

Figure 8: Direct cost Classification for GFRG system with respect to calculation unit

Source: by Author

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DISCUSSION

Glass Fibre Reinforced Gypsum system direct cost model

GFRG system direct cost will discuss the cost model for different items in form of schedules, which will achieve the direct cost model for the system. The researcher assumed the currency for direct cost calculation to be in Dollars. With respect to survey performed with contractors using GFRG system, the operation time estimated for fixation of one GFRG panel is half an hour. The working days for construction process are assumed to be 300 day per year. In addition to that working hours is assumed to be 8 hours per working day.

GFRG Panels and Accessories

This section will discuss the direct cost for GFRG panels and Accessories will be used in fixation of panels. Cost of GFRG panels will be calculated per meter square. Accessories for GFRG are divided into studs, joint table mesh & corner mesh. With reference to survey performed with contractors, one meter square of GFRG panels require 0.4 m of studs& 0.2 m of corners mesh. Figure 9 & 10 will calculate direct cost for GFRG panels and accessories used per meter square.

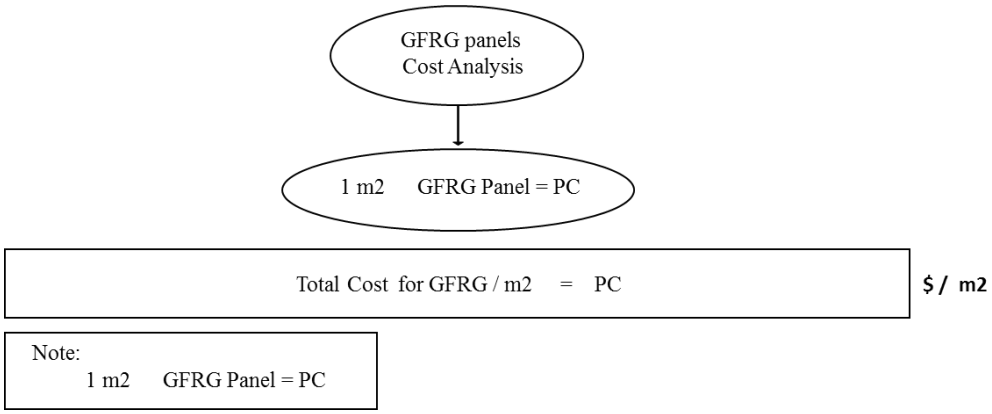

Figure 9: GFRG panels Cost Analysis

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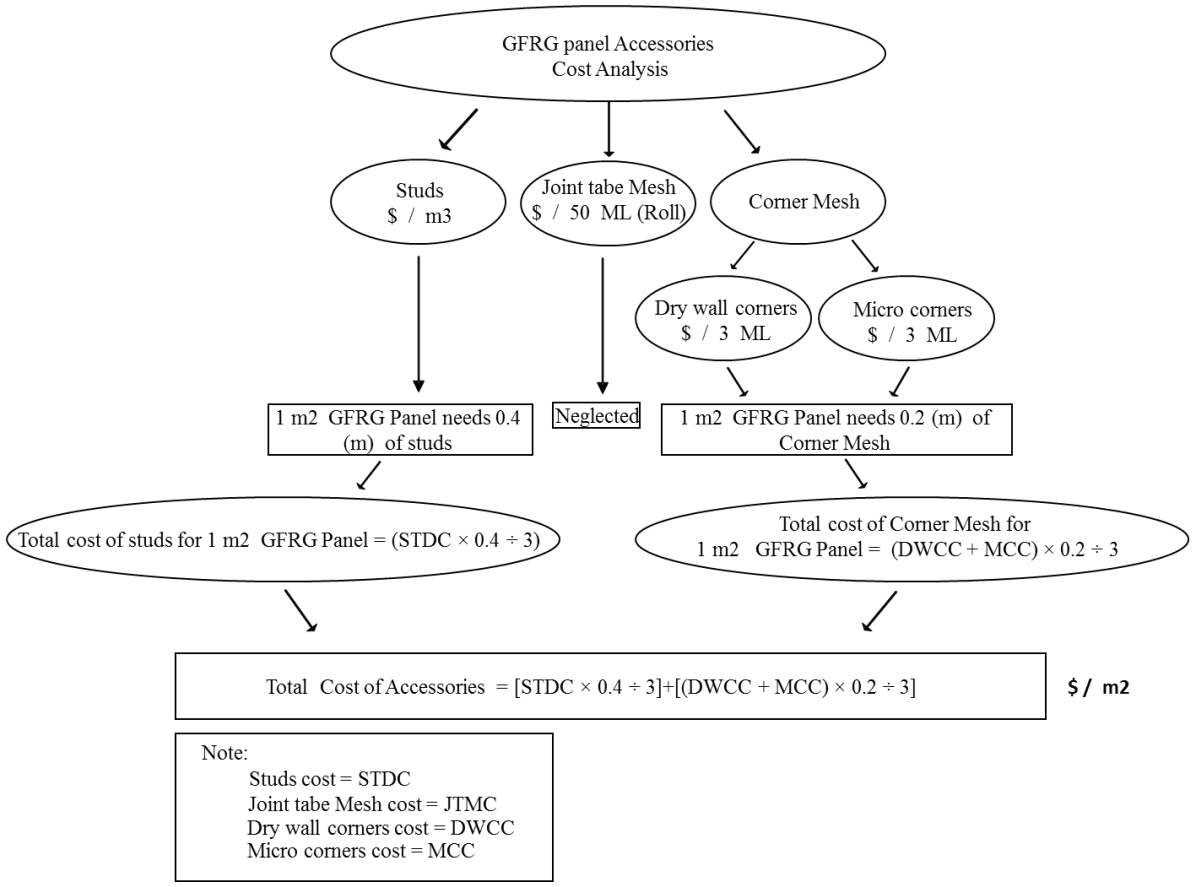

Figure 10: GFRG panels Accessories Cost Analysis

Source: by Author

Electric hand tools

This section will discuss the direct cost for GFRG electric hand tools will be used in fixation of panels. The life cycle for electric tools is assumed to be 1 years, it is assumed that year contains 300 working days; the working day contains 8 hours per day. The cost for electric tools will be calculated per hour. Figure 11 shows the calculations for electric hand tools direct cost.

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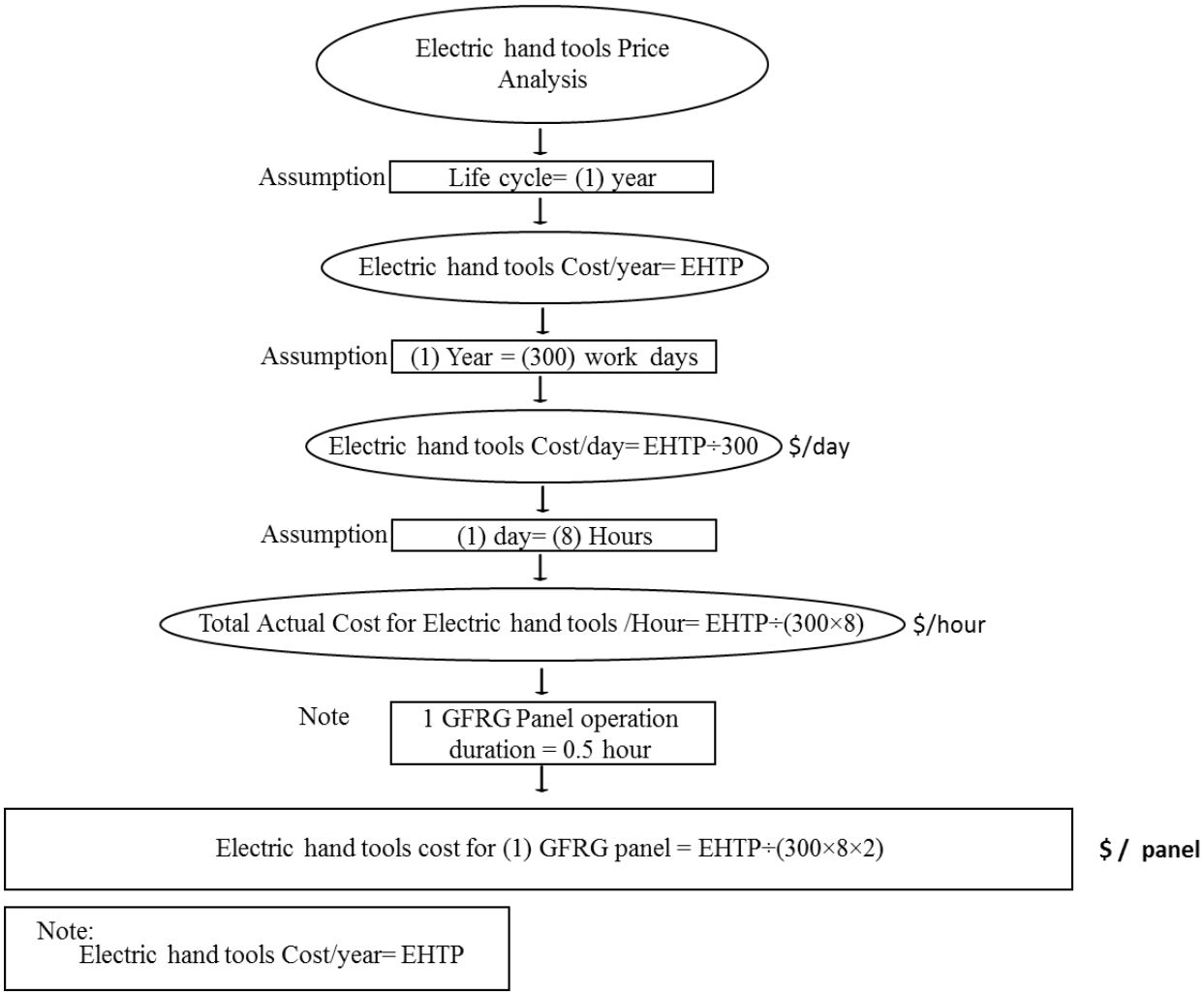

Figure 11: Electric hand tools Price Analysis

Source: by Author

Crane cost

This section will discuss the direct cost for crane will be used in fixation of panels. The life cycle for crane is assumed to be 10 years, it is assumed that year contains 300 working days; the working day contains 8 hours per day. The cost for crane will be calculated per hour. Figure 12 shows the calculations for crane direct cost.

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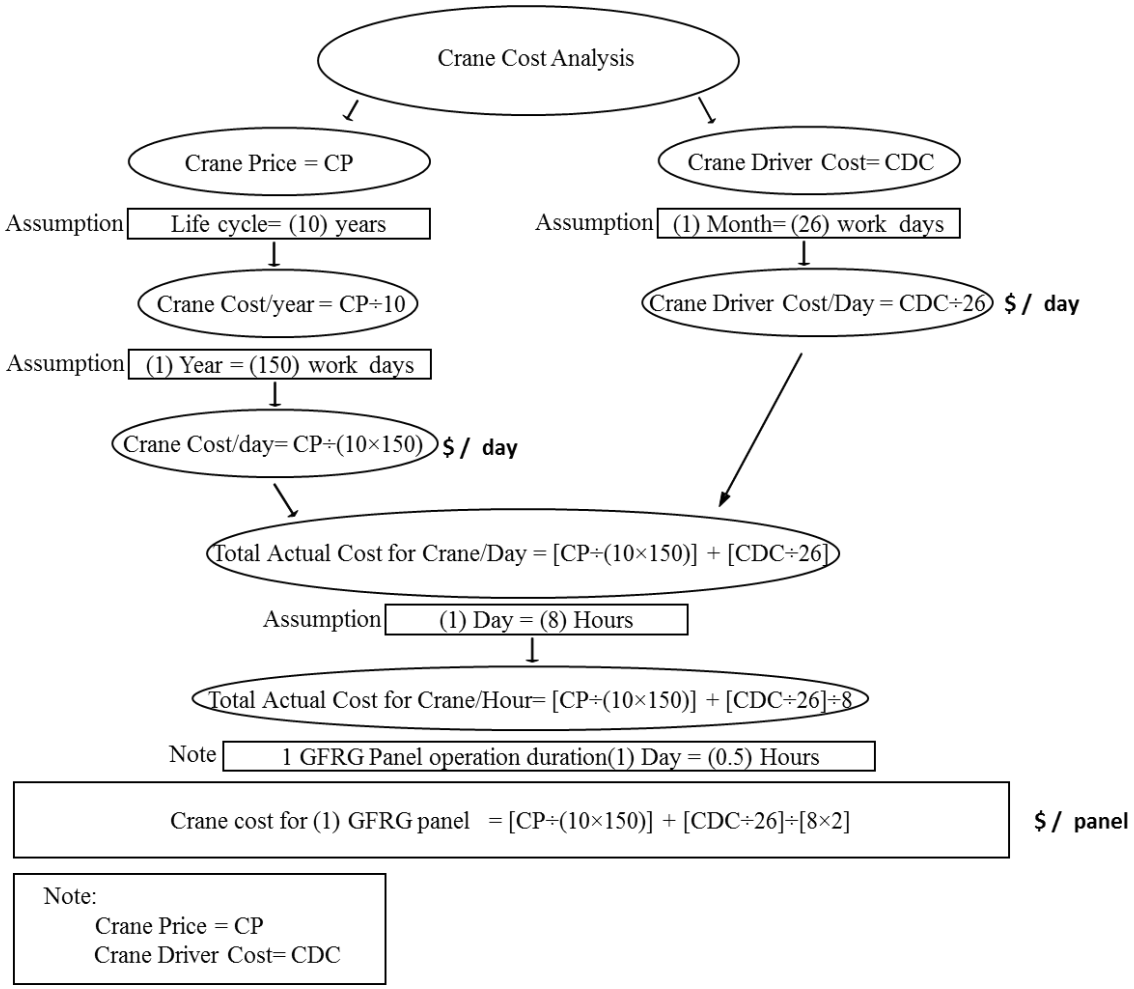

Figure 12: Crane Cost Analysis

Source: by Author

Labour cost

This section will discuss the direct cost for manpower will be used in fixation of panels. With respect to survey performed with contractors, it is assumed that the process of GFRG panel fixation requires one engineer, three technicians & two workers. It is assumed that year contains 300 working days; the working day contains 8 hours per day. The cost for labour will be calculated per hour. Figure 13 shows the calculations for crane direct cost.

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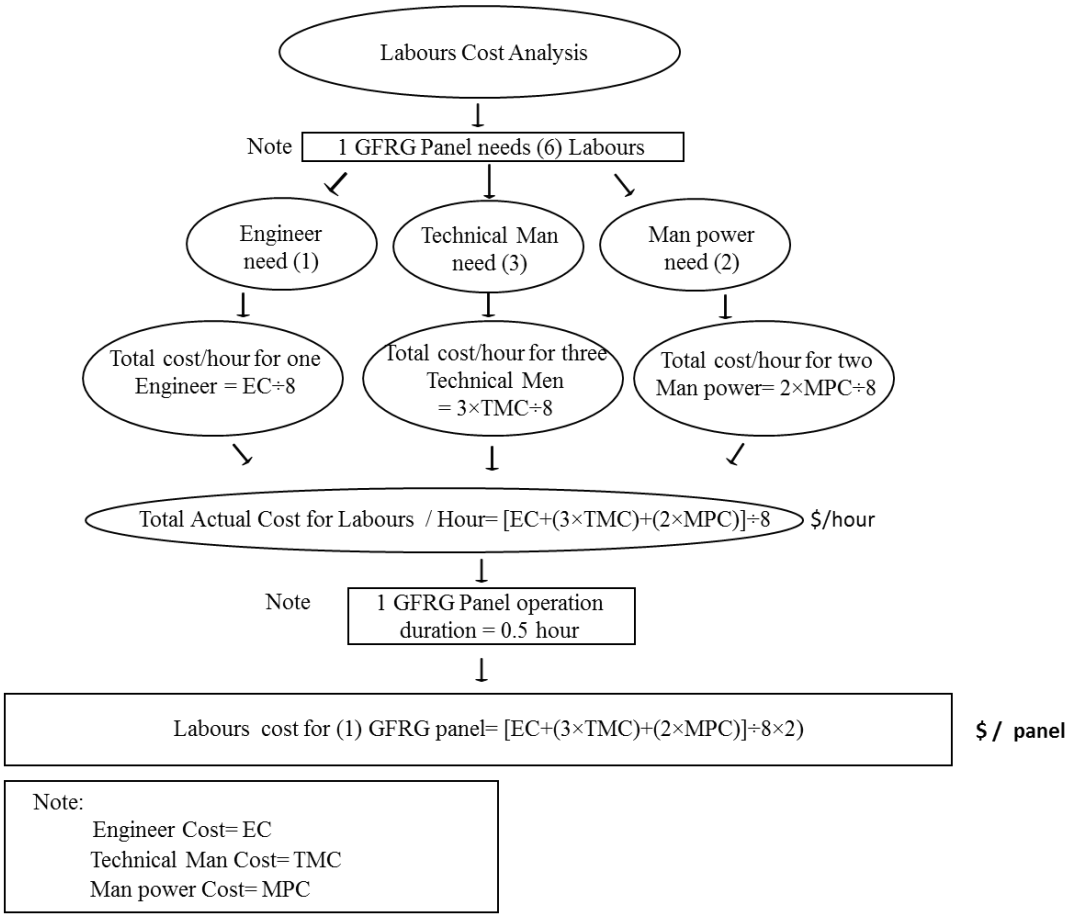

Figure 13: Labours Cost Analysis

Source: by Author

Reinforced concrete cost

The reinforced concrete cost is divided into two categories; first cost of sub-structure cost for the footing & second the cost of super structure for slabs and Reinforced concrete walls. The panels may be unfilled, partially filled or fully filled with reinforced concrete as per the structural requirement.

Sub-structure cost: Figure 14 discusses direct cost for Reinforced concrete footing of the building, which will be calculated as foot print area of the building with depth of Reinforced concrete for the footing multiplied by reinforced concrete cost (RCC). The depth of the footing will be calculated by the structure team according to structure calculations.

Super Structure cost: Figure 15 discusses the super structure of GFRG system for reinforced concrete filling the wall cavity, while Figure 16 discusses the super structure of GFRG system for reinforced concrete for slabs.

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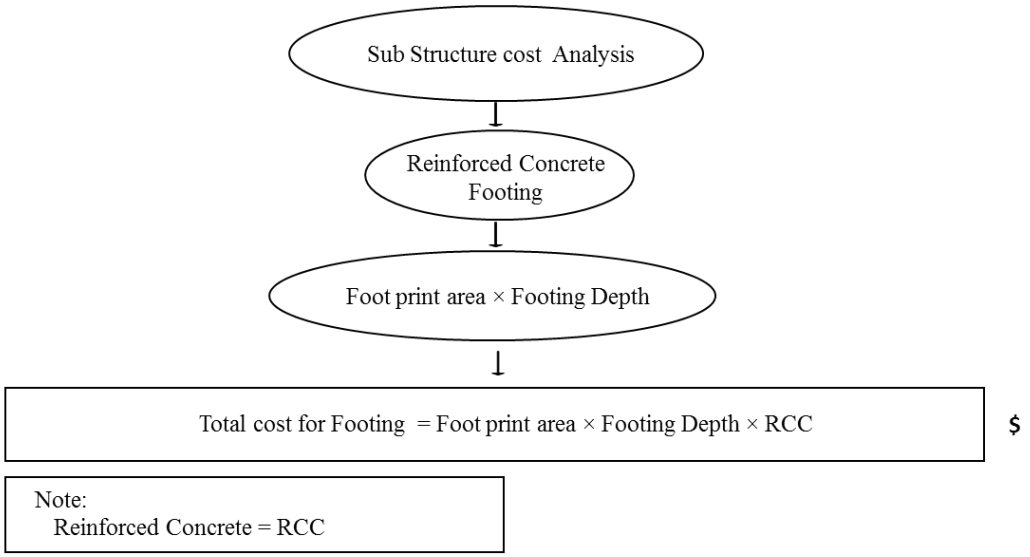
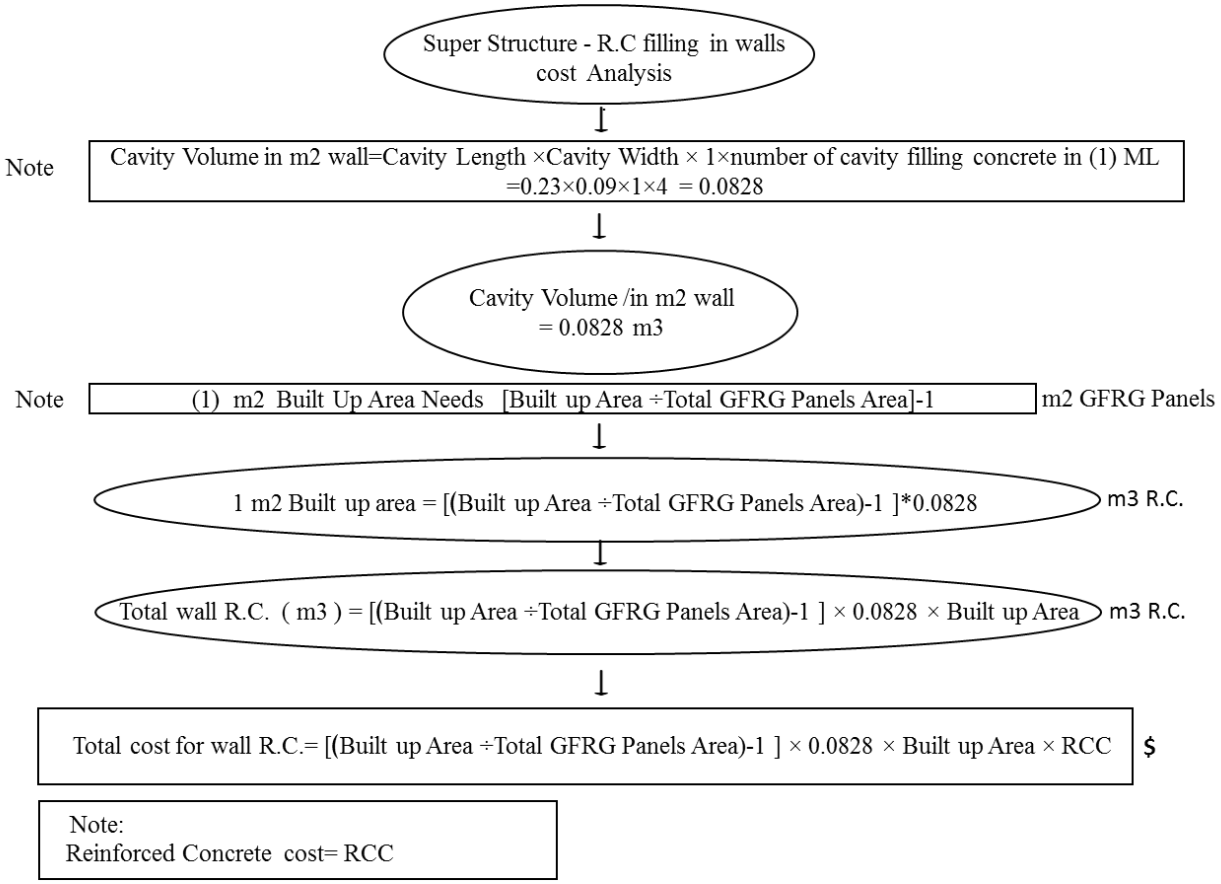


Figure 14 Sub Structure cost Analysis

Source: by Author



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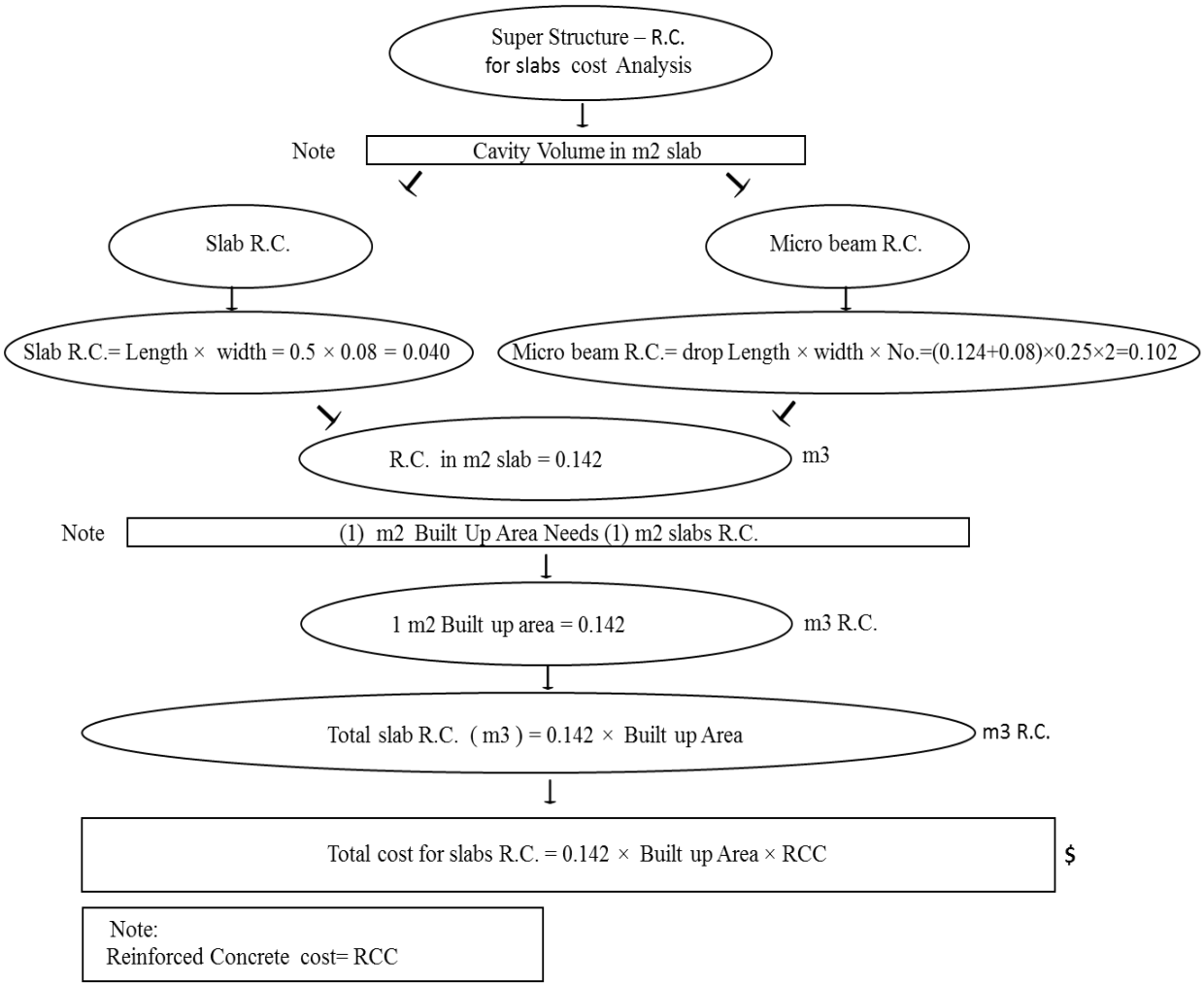

Figure 15 Super Structure - R.C filling in walls cost Analysis

Source: by Author

Figure 16 Super Structure – R.C. for slabs cost Analysis

Source: by Author

IMPLICATION TO RESEARCH AND PRACTICE

The insights given by the findings in this study could have implications for owner and designers to identify the direct cost analysis at the early stages of design phase for the project. GFRG provides high quality and less time compared to traditional systems. The cost for GFRG is more than traditional system, as GFRG is using high technology; in addition to that it saves more time during implementation. GFRG is more efficient and less cost for repetitive projects or mass-scale building construction, in order to increase economic value of GFRG system. The owner/ designer would seek optimization usage for GFRG panels during design stage, which will have positive impact concerning cost of project.

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The cost model will be useful for owner/ designer to study the direct cost estimation for buildings using GFRG system in order to study the cost feasibility of project during design stage to achieve successful investments.

CONCLUSION

We can calculate the direct cost of GFRG system for buildings, assuming that there is three hundred working days per year, eight working hours per day & one GFRG panel is operated in half an hour, and knowing the foot print and built up area for the building as shown in following formula.

GFRG Direct Cost Formula

	PC + [STDC × 0.4 ÷ 3] + [(DWCC + MCC) × 0.2 ÷ 3]	×	Panel meter square
+	EHTP÷ [300×8×2] + [CP÷ [10×150)] + [CDC÷26] ÷ [8×2] + [EC+ [3×TMC] + [2×MPC)] ÷ [8×2]	×	Number of panels
+	Foot print area × Footing Depth × RCC + [(Built up Area ÷ Panels Area)-1] × 0.0828 × Built up Area × RCC		

FUTURE RESEARCH

The future research needs to direct the following aspects:

1- This research aims to study direct cost for GFRG, it neglects the indirect cost for this system. For further cost analysis, future research needs to study the indirect cost which will result for more accuracy calculation of GFRG cost during design phase for the project.

2- The future research needs to study the Risk analysis for using of GFRG system in repetitive project; this will help the owner/ designer to anticipate the cost for GFRG system during design phase.

3- Future research needs to inspect new techniques to decrease the cost for GFRG system with same performance for system.

4- Environmental aspects can be addressed in future researches to study environmental performance for spaces using GFRG system.

5- Future studies can address the quality procedures for installation inspection for GFRG system on site.

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