IMPACT OF REWORK ON COST AND DURATION OF CONSTRUCTING REINFORCED CONCRETE STRUCTURES

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Abstract

Rework is one of the major determinants of construction productivity. This thesis aimed at investigating the reworks in constructing reinforced concrete structure by determining the wasting cost and time delay due to rework, identifying rework factors, and exploring the frequency and effect of rework items in project cost and time. Cost and time effect of rework items were also investigated in this research. The most important effect of rework is on productivity and productivity influences cost, time, and quality within the construction project. This study aims to investigate the impacts of reworks on cost and duration of construction of reinforced concrete structure, determining the share of factors such as contractors, owners, and consultants in cost of rework, and inquire the rework items in terms of their frequency and effect on cost and time. The methodology used in this study was case study and questionnaire survey. The case study project was three blocks of 8-storeys residential buildings with reinforced concrete structure and the total construction area of 12000 square meters. The data collection was through the personal observation and also interviews of the civil engineer supervisors. In addition to the case study, a questionnaire survey was conducted among medium to large size reinforced concrete construction projects. 22construction projects contributed to this survey. From the case study and questionnaire survey it is founded that rework has an impact on cost and duration of constructing reinforced concrete structures. So it is clear that further analysis is needed on this topic to find the impact of rework.

I. Introduction

1.1 General

The importance of construction industry is approved in all communities.It is one of the major industries in the economic growth and civilization. A huge amount of money, time and energy consuming in this part indicate the important role of this industry. Construction industry not only includes buildings construction, but also covers roads, bridges, dams and skyscrapers construction.

The most important effect of rework is on productivity and productivity influences cost, time, and quality within the construction project. The enhancement of productivity has many advantages such as reducing total cost and production duration, improving quality, increasing product market share, and increasing salaries and employment. Generally, productivity growth is the most important economic indicator through it fast living standard growth could be attained.

This study aims to investigate the impacts of reworks on cost and duration of construction of reinforced concrete structure, determining the share of factors (contractors, owners, and consultants) in cost of rework, and inquire the rework items in terms of their frequency and effect on cost and time. For this purpose, a project consisted of three 8-storeys building was observed and studied as a case study and a questionnaire survey was undertaken among 22 construction projects

1.2 Objective

The objectives of this thesis are

-1. To identify the rework items that frequently happen in constructing reinforced concrete structure.

2. To investigate the rework items in terms of their frequency, and cost and time effect in constructing a reinforced concrete structure.

3. To specify the impact of rework on cost and duration of constructing reinforced concrete structure.

4. To determine the share of rework factors including contractors, owners, and consultants in rework cost

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1.3 Scope of study

The general scope of this research are improving the construction quality and eliminating the cost of waste and time delay due to rework through the use of a case study and conducting a questionnaire survey and by focusing on rework as one of the major problems in construction industry**.**

1.4 Works Under Taken

These works were undertaken in this project:

1. A case study project was selected, construction activities were observed and interviews were taken.

2. Cost and time impact of rework and factors share in cost of rework in case study project were determined.

3. A questionnaire survey among 22 construction projects was undertaken.
4. The effects of rework on project cost and time, and the share of rework factors in cost of surveyed projects were prescribed and compared with the results of case study.
5. 17 rework items were investigated, their frequencies were ascertained, the correlations among rework items were found out through running a factor analysis, and cost and time effects of rework items were estimated by calculating their importance.

II. Literature review

2.1"REWORK ON CONSTRUCTION COST PERFORMANCE

"Measuring the Impact of Rework on Construction Cost Performance*"*Bon-Gang Hwang; Stephen R. Thomas, M.ASCE; Carl T. Haas, M.ASCE; AND Carlos H. Caldas, M.ASCE

Rework continues to affect both cost and schedule performance throughout the construction industry. The direct costs alone often tally to 5% of the total construction costs. Using the data obtained from 359 construction projects in the Construction Industry Institute database, this paper assesses the impacts of rework on construction cost performance for projects in various categories. In addition, it identifies the sources of this rework, permitting further analyses and the development of rework reduction initiatives. The results of this study establish that the impacts of rework differ according to project characteristics and that the sources of rework having the greatest impact are not significantly different among project categories. By recognizing the impacts of rework and its sources, the construction industry can reduce rework and ultimately improve project cost performance

2.2 " REWORK TYPES ON PROJECTS

"The Effect of Project Types on the Occurrence of Rework in Expanding Economy*"*L. O. Oyewobi, A. A. Oke, B. O. Ganiyu, A. A. Shittu, R. B. Isa And L. Nwokobia

Construction projects are complex in nature because they entail complex activities characterized with uncertainties and changes that are capable of increasing time and cost of construction projects. Rework is a waste that involves doing certain task more than once, it may not be totally eliminated but it is avoidable. It occurs as a result of so many factors ranging from omission or error in design, construction failure, and change order to inadequate coordination and communication among stakeholders on the project. Hence, to enhance project performance it becomes imperative to identify the influence of project type on the occurrence of rework. This paper presents analyses and discusses the rework costs experienced by the studied projects and the findings revealed that the cost of rework for new buildings understudied was averagely 5.06% as against 3.23% recorded by refurbished buildings of the completion cost. Therefore, to improve project performance and to reduce the menace of rework costs, it is asserted there is need for consensus to be reached on a workable mechanism to bring together the client and the contractor to minimize change orders and introduction of additional works during construction phase

2.3 "REWORK REDUCTION IN CONSTRUCTION

"A Rework Reduction Model for Construction Projects"
Peter E. D. Love, Zahir Irani, and David J. Edwards

I Rework is an endemic problem in building construction projects and is an area of research that has received limited attention. Recent research has shown that rework is the primary cause of time and schedule overruns in projects and that rework levels do not significantly differ between current procurement methods despite calls from government for the use of more integrated procurement approaches such as design-and-construct to improve project performance. Changes initiated by a client or occupier when a product or process had been completed and design scope freezing were factors identified as contributing to rework. To reduce the incidence of rework throughout the construction supply chain, data from 161 completed projects were gathered using a questionnaire survey. Stepwise multiple regressions were used to determine the significant variables that contributed to rework in projects. In conjunction with previously reported research, these variables were used to develop an alternative procurement model for reducing rework in projects. It is suggested that the proposed model could be used to stimulate inter-organizational relations and promote teambuilding during the formative stages of a project, which is essential for reducing design-related rework.

2.5 REWORK CAUSES

To enhance the quality it is essential to realize the fundamental causes of rework as the major reason of rework existence or set of conditions that induce its happening in a process. A number of operations or activities which acting on inputs and transform them to the outputs make a process. A process may comprise value adding activities or non-value adding activities. Value adding activities commute materials or/and information towards the customer requirements and non-value adding activities take time, resource or require storage without adding value to the final output. Put differently, a non-value activity (such as rework) is waste. Rework models contribute to better understanding of the body structure of rework. Characteristics of rework and rework factors are determined by the models. Various models of rework are represented in this section.

Rework category model proposed by Wasfy is shown in Figure 2.1. It is composed of two major categories of factors cause rework, direct rework causes and indirect rework causes. Direct rework causes are the factors that directly lead to rework occur and they consist of insufficient supervision, incompetent supervision, poor workmanship, wrong material, defective material, deviations from drawings, and errors and omissions in drawings. Indirect rework causes refer to a group of causes that they do not cause rework themselves but they create the situations that will cause rework. These indirect rework causes are: selection of improper subcontractor, improper work protection, lack of coordination, and improper work sequencing.

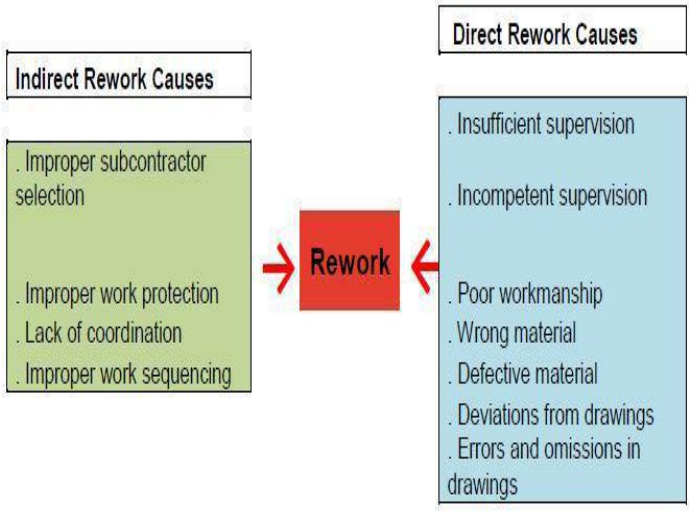

Figure2.1 Rework categories

III. Methodology

3.1 General

This chapter consists of two main sections, case study and questionnaire. Specifications of the projects and the method of collecting data are provided in this chapter

1.SITE VISIT
2.DATA COLLECTION
3.QUESTIONNAIRE SURVEY
4.DATA ANALYSIS
5.CONCLUSION

3.2 CASE STUDY

Construction projects in Trivandrum was chosen as a case study project.

Project Specifications

The case study project was three blocks of 8-storeys residential buildings including 2 stroreys of parking and storage, and 6 residential storeys. Number of residential units of each floor was 5, so each block comprised of 30 residential units and the total number of units of the project was 90. Each residential floor consisted of 1 one-bedroom unit, 2 two-bedroom units, and 2 three-bedroom units with the area of 73, 100, and 127 square meters of each unit, respectively. The total construction area was 12000 square meters. The volume of soil excavation of each block was 1700 cubic meters with the excavation area of around 500 square meters (28.5×17 meters) and the excavation height of 3.5 meters. Excavation was done mechanically by using loader for digging and truck to transfer the soil.

According to the results of soil test, constructing the pile under the foundation was needed. 6 circular reinforced concrete piles with a diameter of 1 meter and length of 8 meters with the same concrete specifications of foundation were constructed for each block. 10 centimeters of blinding concrete was placed on the soil. The total volume of cleaning concrete was 45 cubic meters with the cement ratio of 150 kilograms per cubic meter, which was transferred from batching plant to the site.

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3.3 Contractual and Supervision Conditions

Excavation phase of construction was done by the owners as they had excavation machines. The construction of structure including foundation, columns, beams, shear wall, and slabs was contracted by bidding. According to the tenders condition, construction materials were provided by the owners and construction work was done by the contractor. The main contractor constructed the structure by hiring subcontractors for reinforcing, formwork and concrete work. One full time site manager monitored the construction site on behalf of the owners to proctor the performance of the contractor and organize construction works in different phases. A construction company full-time supervised the building operations on behalf of the civil engineering organization of the city. According to the law, every construction site should be supervised by a registered construction company in order to get necessary permissions. In addition, the construction site was part-time inspected by the engineers of the municipality.

3.4 Data Collection

Data collection was done by observing the construction and also through a personal interview. Most of the interviews were taken from the supervisor of civil engineering organization as their data were most reliable.

The questions that were asked as follow:

1. How much money is wasted due to rework in percent of construction costs?

2. How long delay is happened due to rework in percent of construction period?

3. What are the percentage share of each factor such as contractor, consultant, and owner in the rework cost?

4.What are the reworks in excavation, reinforcing, formwork, and concrete work?

As there were more than one owner in this project, the owner means a group of owners. The full time site manager which has the responsibility on behalf of the owner acts as consultant in this case, and the meaning of contractor is the person or organization which was awarded the tender and was responsible for the construction.

3.5 QUESTIONNAIRE

In addition to the case study, a questionnaire survey was undertaken among 22 construction projects.

3.6 Projects

22 Construction projects of reinforced concrete building were chosen for this survey. The projects were residential apartments. Selected projects were medium to large in size, as they ranged between 5000 to 16000 square meters of construction area.

The projects were supervised by the construction organization which issues their permission and also they were inspected by the engineering of the municipality. This indicates that the minimum quality requirements were fulfilled in these projects. The minimum construction experience of the contractors was 5 years.

3.7 Data Collection

The questionnaire was designed to cover the aims and objectives of the research which are:

- To find out the cost of reworks in reinforced concrete construction.
- To determine the delay due to reworks.
- To identify the share of contractor, owner, and consultant in cost of reworks.
- To figure out the frequency of happening of rework items.
- To categorize the rework items of in each phase of constructing reinforced concrete structure.

3.8 DATA ANALYSIS AND DISCUSSIONS

Results of the study and their analysis are provided in this chapter with their explanations and discussions. This chapter is divided into four sections, the first section represents the cost of rework in the construction of reinforced concrete structure, the second section covers the time wasting of rework in the stated phase of construction, the third section presents the factors of rework (contractor, owner, consultant) and the influence of each one in the cost of rework, and the final section provides some rework items in different phases of construction, relations between the items of each phase, their frequency, and their effect on cost and time of rework. All analysis and charts are done and drawn by Statistical Package for Social Sciences or SPSS software version 20.

3.9 Rework Cost

In this section, rework cost is given as a percentage of the construction cost of building a reinforced concrete structure. The average of rework costs of all projects are then calculated as the mean of rework cost. The result of observations and data collection fr3om case study project showed that the cost of rework was Rs.21,00000. This amount was gained by summing up the cost of rework items (The sample of rework items are given in the section 2.5) that happened during the construction. The construction activities that considered in this study were excavation, reinforcing, formwork and concrete work of constructing reinforced concrete structure. The total cost of construction was Rs.11,34,00000. By dividing the cost of rework to the construction cost, it is found that the rework cost is around 1.85% of the construction cost during the observation period. It means that for the construction of reinforced concrete structure in the case study project, this amount of money is wasted due to rework.

The rework costs of 22 construction projects are shown in the Figure 4.1. This figure shows the frequency of each rework cost among the projects. The horizontal axis represents different rework costs in percentage of construction cost and the vertical axis indicates the frequency of each rework cost among the surveyed projects. The results are according to the data collected by a questionnaire survey from different constructing or constructed projects.

3.10 Rework Time

Rework times are provided as a percentage of the period of constructing reinforced concrete structure in this chapter. The time wastage of rework in the case study project comes first and the rework times of the 22 surveyed projects come after.

In the case study project, time delay due to rework was observed as 15 days and the duration of constructing the structure was 365 days so, the rework time in the case study project is 4.1% of the construction period. The mentioned time delay is the wasting time to make the rework items correct.

By a questionnaire survey, rework time of 22 construction projects were gathered and it is shown in the Figure 4.2. Different rework times in percent of construction duration are given in the horizontal axis and the frequency of each rework time among 22 surveyed projects are demonstrated in the vertical axis. It indicates the frequency of each rework time among the projects. In the figure, rework time are given as a percentage of construction period.

3.11 Rework Factors

Rework factors that investigated in this study are: contractor, owner, and consultant. The role of factors is shown as the percentage of rework cost happened because of each ones mistakes

Contractor

In the case study project, contractors were the most responsible factor in the costs of rework and it made 46% of rework costs. The results of survey are given in the Figure 4.3. In this figure, horizontal axis shows different percentages of the share of contractor in the rework cost and vertical axis indicates the frequency of each number among 22 surveyed projects.

Owner

The share of owner in the cost of rework in the case study project was 37% of the rework cost, indicates that owner is the second most important factor in the rework cost after contractor. According to the survey of 22 construction projects, the owner's shares in the rework cost are shown in the Figure 4.4. In this figure, horizontal axis represents various percentages of the share of owner in rework cost and the vertical axis determines the frequency.

Consultant

The share of consultant in cost of rework in the case study project was observed as 17%. The results of survey from 22 constructions projects are given in Figure 4.5. Horizontal axis in this chart indicates different percentages of shares of consultant in rework cost and vertical axis shows the frequency among surveyed projects.

Rework Items

The rework items observed in the case study project and typical items that occur in most of the construction of reinforced concrete structures are investigated in this research. These items are:

1- Over excavation.
2- Collapsing excavation walls.
3- Appearing cracks at the corners of concrete elements.
4- Displacement of formwork at the time of placing concrete.
5- Falling formwork materials from top storeys that causes damage to them.
6- Bad appearance of concrete surface caused by deformation of formworks.
7- Fabricating inaccurately dimensioned concrete elements.
8- Damaging formwork materials due to irregular shapes with non-standard sized modular panels.
9- Leaking concrete from joints of the formwork.
10- Changing the designed steel bar diameters due to unavailability.
11- Wasting the reinforcement bars by wrong workmanship.
12- Remaining reinforcement bars at the end of construction.
13- Lacking reinforcement bars.
14- Using inappropriate head for poker vibrators.

15- Forming cold joint due to mismanagement of concrete delivering to the site.
16- Allocating inappropriate concrete materials.
17- Demolishing or repairing some parts of concrete due to non-conformance to the specification.

IV. CONCLUSION

Rework is one of the major determinants of construction productivity. This thesis aimed at investigating the reworks in constructing reinforced concrete structure by determining the wasting cost and time delay due to rework, identifying rework factors, and exploring the frequency and effect of rework items in project cost and time.

The methodology used in this study was case study and questionnaire survey. The case study project was three blocks of 8-storeys residential buildings with reinforced concrete structure and the total construction area of 12000 square meters. Excavation was done by owner and the construction of reinforced concrete structure was done by main contractor. Main contractor hired subcontractors for execution. The data collection was through the personal observation and also interviews of the civil engineer supervisors. In addition to the case study, a questionnaire survey was conducted among medium to large size (Ranged between 5000 to 16000 square meters of construction area) reinforced concrete construction projects. 22 construction projects contributed to this survey.

The results of case study project showed that the cost of rework is 1.85% of the construction cost and time delay due to rework is 4.1% of the duration of constructing reinforced concrete structure. After analyzing the data, similar results were obtained from the questionnaire survey. Survey results indicated that, around 2.1% of the construction cost and 5.18% of the construction time was wasted due to rework. In the case study project, the share in rework cost was determined as: 46% of contractor, 37% of owner, and 17% of consultant. The relative results of the questionnaire survey indicated that, contractors had almost 49% of the share of rework cost, owners had around 31%, and the share of consultants in rework cost was almost 20%.

Cost and time effect of rework items were also investigated in this research. For this purpose, importance index of each rework item was calculated by multiplying frequency index and severity index which explained in the methodology chapter. The rework items of each phase of construction and the total rework items were ranked by their importance in cost and time effect separately. Referring to the results, allocating inappropriate concrete materials, changing the designed steel bar diameters due to unavailability, and forming cold joint due to mismanagement of concrete delivering to the site were the most three effective rework items in cost waste due to rework. Collapsing excavation walls, over excavation, and falling formwork materials from top storeys that causes damage to them were three items with the most influence on time delay due to rework.

V. RECOMMENDATIONS

To reduce the frequency of rework and eliminate cost wasting and time delay due to rework the following precautions are recommended:

1. Owners should avoid involving in construction works such as holding tender directly. It is recommended to assign them to the consultant or representative who is familiar with technical issues.
2. Owners should hire the construction manager to do cost and time management, organize the contracts, select the suitable construction methods or materials and observe the construction process.
3. Having a fulltime supervisor in the project site to prevent the rework or make the wrong implemented works correct on time is recommended.
4. Preventing reworks to happen by considering the technical competency of the contractors. Most of the time the best contractor to select is not who offered the lowest price as there are hidden costs such as rework cost with them.
5. Owners should avoid of making changes in plan or materials at the time of construction.
6. Try to make the missions and possibilities of the contractors, consultant, and management team clear by writing proper contracts.
7. Designers are recommended to use one number of steel bars instead of using similar numbers.
8. Do not utilizing substandard materials in construction.
9. Managing the available reinforcement bars and avoid of buying more or less amount of bars than are needed for construction.
10. Protecting excavation walls from falling by constructing a proper structure.
11. Defining the excavation area clearly before excavation.
12. Hiring trained workmanship.
13. Managing the concrete resources by defining the required number of trucks based on the capacity of the concrete source.
14. Providing concrete from trusted source.

VI. SCOPE OF FUTURE WORK

It is recommended to do further studies on rework in the following areas:

1. Cost and time impact of rework in construction industry.
2. Investigating rework items and factors in construction.
3. Cost and time impact of rework in constructing different types of structure and make comparison.

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