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# A Study on Impacts of Wastage and Delay in Rework of Reinforced Concrete Structures

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***Abstract- In the construction industry, rework is one of the major reasons that affect the success of a project. It leads to lessen the quality and productivity, and rises the cost and time of construction. Rework often happens due to poor supervision, insufficient workmanship, incorrect or faulty materials, etc. This project aims to find out the cost of waste and time delay due to reworks in the construction of RC structures, to explore the elements influencing the rework such as contractors, owners, and consultants. Also in this project the rework things, their frequencies, their relationship, and their influence on cost of waste and time delay were inquired. Here is a case study project consisted of three 8-storied buildings was examined and studied, and a questionnaire survey was carried out to collect data. The case study and questionnaire survey discovered that, the reworks affected the cost by 1.80% and 2.0% of construction cost respectively. Also the discovery revealed that, the time delay of rework in case study and survey was 4.0% and 5.15% of construction time respectively. It was attained that, the major rework things that affecting the cost were: 1- allotting unsuitable concrete materials, 2- altering the designed steel bar diameters due to scarcity, and 3- formation of cold joint due to inefficiency of concrete delivering to the site. The major rework things that affecting the delay were: 1- falling excavation walls, 2- over excavation, and 3- falling down formwork materials from top stories.***

## INTRODUCTION

The importance of construction industry is validated in all communities. An immense amount of money, time and energy consuming in this part specifies the major role of this industry. Construction industry not only comprises building construction, but also covers roads, bridges, dams and skyscrapers construction. In the process of construction, inaccuracy frequently occurs and they lead to reworks in different stages of construction. In general, reworks and wastages are affect the productivity and performance in construction projects and probably the most complete definition of rework is "the procedure that is making an item to adjust with the original requirements by correction or completion". Rework may occur because of the lack of quality control, insufficient maintenance, using unskilled labors and inadequate tools, etc. The reworks sometimes are happening as demolishing and rebuilding and sometimes as requirement of extra works.

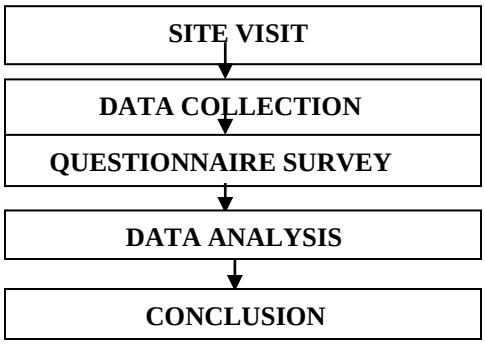
The major effect of rework is on productivity and productivity impacts cost, time, and quality within the construction project. The increase of productivity has many advantages such as reducing total cost and production duration, enhancing quality, increasing product market share, and increasing salaries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

This study aims to explore 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 investigate the rework items in terms of their frequency and effect on cost and time. For this purpose, a project consisted of three 8-storied building was observed and studied as a case study and a questionnaire survey was undertaken among 2 construction projects.

The rework cost in percentage of construction cost and the rework time in percentage of construction duration in case study project were evaluated according to the observations and interviews, and the relevant cost and time in surveyed projects were estimated as the mean of rework costs and times of all projects. The share of each factor in rework cost was investigated in case study project, and in questionnaire survey it was measured as the average of each factor's share among surveyed projects. 17 rework items were explored in

questionnaire survey and the frequency of each item was determined as the number of happening among 2 surveyed projects. The cost and time effects of each rework item were acquired by multiplying their importance index, which was gained from questionnaire, and frequency index.

METHODOLOGY




Project Specifications

The case study project was three blocks of 8-storied 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 comprised 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 by using loader for digging and truck to transfer the soil.

Based on 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.

The kind of foundation is mat foundation. 450 cubic meters of concrete were placed to construct the foundation of each block and this was done by discharging 65 truck mixers which transferred the concrete from batching plant of the Fars cement company. The thickness of foundation was 90 centimeters and it was constant for the whole foundation. The weight of reinforcement of each block‘s foundation was 30 tons including two layers of steel bars at the top and bottom, and confirmatory bars. The essential strength of foundation concrete was 250 kilogram per square centimeter for the 28 days cylinder sample. One concrete sample test was taken for every 50 cubic meters of concrete. Steel formwork was used and concrete was cured for 8 days by keeping it wet and under normal temperature condition.

The structure of building was reinforced concrete with shear walls, and two-way slabs for the roofs. Rectangular columns started with dimension of 50×50 centimeters on the basement and they reduced to 40×40 centimeters at the top. Dimension of beams was 40×40 centimeters and it was the same for all floors. The thickness of basement‘s roof was 17 centimeters which was constructed by using two layers of steel bars or mesh, and the roof thickness of other floors were 15 centimeters. 2 ducts were passed through the slabs of top 6 storeys and 12 ducts from second floor to the top. 21 shear walls were constructed for each block of the project including: 5 shear walls with the thickness of 35 to 45 centimeters from the basement to the top, 9 shear walls with the thickness of 30 centimeters just in the underground floor, 5 shear walls with the same thickness for the first two floors, and the rest 2 shear walls with the thickness of 20 centimeters from the second floor to the top. Each shear wall included two layers of steel bars.

For the structural concrete works metal formworks was used. The concrete volume of the top 6 storeys was 140 cubic meters for each floor and the designed strength of concrete for structure comprises columns, beams, shear walls, and roofs was 300 kilograms per square centimeter for the 28 day cylinder sample. For every column and shear wall, one concrete test was performed.

Data Collection

Data collection was done by perceiving the construction and also through a personal interview. Most of the interviews of civil engineering

organization were taken from the supervisor as their data were most reliable.

QUESTIONNAIRE

In addition to the case study, a questionnaire survey among 2 construction projects was undertaken.

Projects

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

Data Collection

The questionnaire was prepared to cover the following sections.

Section one covered question about the cost of rework in percentage of construction cost, and time delay due to rework in percentage of construction duration. Second section was prepared to identify the share of contractor, owner, and consultant in rework. The third section of the questionnaire was formed as a table, about the rework items.

For this questionnaire purpose, factors analysis was used by employing the statistical package for the social sciences (SPSS) software version 20. Factor analysis is a technique for recognizing groups of variables. The explored rework items were related to the four phases of constructing a reinforced concrete structure; excavation, reinforcing, formwork, and concrete work. For each rework item, the interviewees were requested to answer the severity on rework cost. A five-point scale of 0 to 4 was take on for evaluating the effect of each factor. These numerical values were assigned to the interviewees rating: 0= No severe, 1= Low severe, 2= Moderate, 3= Very severe and 4= extremely severe. Then severity index is calculated by using the following formula:

$$S.I = \sum a_i n_i / 40\ N \text{ (i ranges from 0 to 4)}$$

Where: a= constant expressing the weight assigned to each responses, n= frequency of each response, and N= total number of responses.

The importance index of item in rework cost is also determined according to the following equation;

$$IMP.I.=F.I\times S.I.$$

For each rework item the severity of its influence on the time of rework was calculated. The importance index in time of rework was also determined. The scale and formulas were the same as the severity on rework cost which were given above.

DATA ANALYSIS

In this chapter, results of the study and their analysis are provided with their explanations and discussions. This chapter is divided into four sections, the first section covers the cost of rework in the construction of reinforced concrete structure, the second section represents the time wasting of rework in the stated phase of construction, the third section involves the factors of rework (contractor, owner, consultant) and the impact of each one in the cost of rework, and the final section constitute some rework items in different phases of construction, relations between the items of each phase, their frequency, and their influence on cost and time of rework.

Rework Cost

In this section, rework cost is given as a percentage of the construction cost of a reinforced concrete structure in a building. The average of rework costs of all projects are then determined as the mean of rework cost.

The result of surveillance and data collection from case study project showed that the rework cost was Rs.21,00000. This amount was obtained by adding the cost of rework items that happened during the construction. The construction activities that examined in this study were excavation, reinforcing, formwork and concrete work of constructing reinforced concrete structure. The total construction cost was Rs.11,34,00000. By dividing the cost of rework to the construction cost, it is obtained that the rework cost is around 1.85% of the construction cost at the observation period. It means that in the case study project, for the construction of reinforced concrete structure, the above mentioned amount is wasted due to rework. Figure.1 shows the frequency of each rework cost among the projects. The horizontal axis indicates different rework costs in percentage of construction cost and the vertical axis represents the frequency of each rework cost among the surveyed projects. The results are according to the data collected by a questionnaire survey from different construction projects.

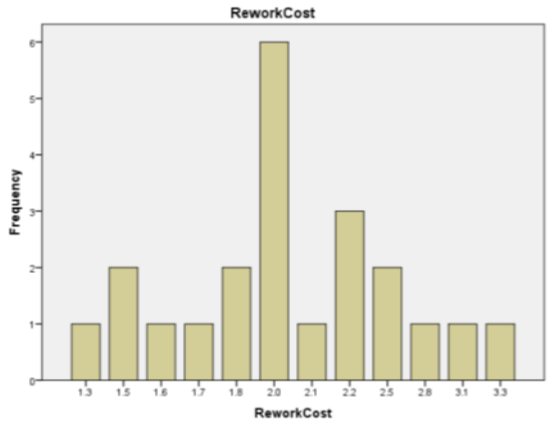



Figure1. Rework costs and frequencies

The cost of rework of the case study project is 1.85% and the mean of rework cost obtained from 2 projects is 2.095%. By comparing the above two values, it is found that there is an about 12% relative difference between these two and it is reasonable because the projects are different in size, conditions, supervisions and etc.

Rework Time

Rework times are mentioned as a percentage of the period of constructing reinforced concrete structure in this chapter. At first, time wastage of rework in the case study project comes and the rework times of the 2 surveyed projects come after.

In the case study project, time delay due to rework examined was 15 days and the duration of constructing the structure was 365 days so, the time for rework in the case study project is 4.1% of the construction period. The mentioned time delay is the wastage of time to make the rework items correct. In the figure.2, rework time are given as a percentage of construction period.

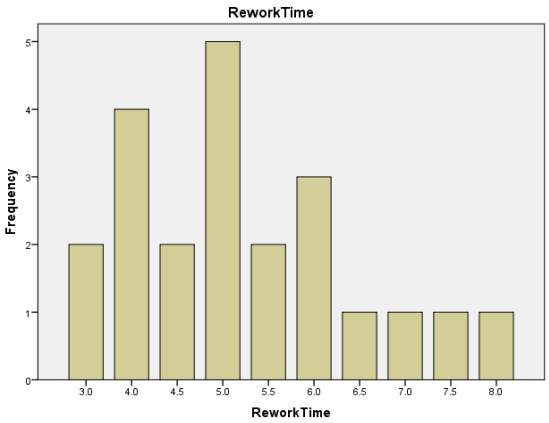



Figure2. Rework times and frequencies

Rework Factors

Rework items that examined in this study are: contractor, owner, and consultant. The role of rework items is shown as the percentage of rework cost happened because of each one‘s mistakes.

Contractor

In this case study project, contractors were more responsible factor in the costs of rework and it made 46% of rework costs.

Owner

The part of owner in the cost of rework in this case study project was 37% of the rework cost, shows that owner is the second most important factor in the rework cost after contractor. Referring to the observed information, 30% and 35% share of owner in rework cost are the most frequent and each one is repeated in 6 projects.

Consultant

The part of consultant in cost of rework in the case study project was observed as 17%. The results surveyed from 2 constructions projects shows the consultant‘s part in rework cost and frequency of repeating in surveyed projects. Based on the questionnaire, the minimum share of consultant in rework cost is 10% and the maximum is 25%. The mean of data is 19.77%.

According to the mentioned data analysis, a chart of factor‘s share in rework cost can be drawn. Part of three factors (contractor, owner, and consultant) in the cost of rework in the case study project is provided as a pie chart in Figure3. It shows that 46% of the cost are of rework caused by the contractors, 37% by the owner, and 17% by the consultant.

Categories of Rework Items

To classify the rework factors, the relations and correlations between each pair of factors should be discovered. For this, factor analysis is done on 17 rework items by utilizing SPSS software version 20.

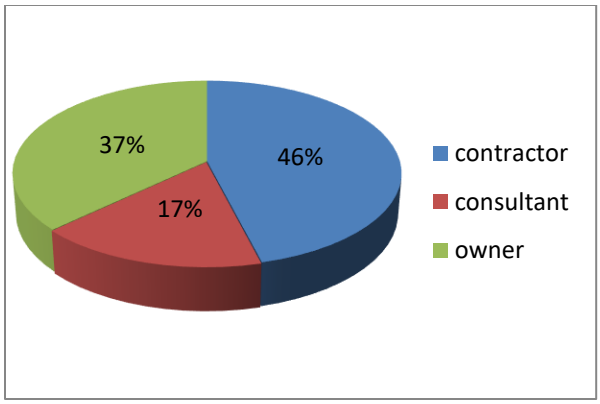



Figure3. Share of three factors in the cost of rework

## CONCLUSION

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

The methodology used in this project was case study and questionnaire survey. The case study project was three blocks of 8-storyed residential buildings with reinforced concrete structure and the total area of construction was 12000 square meters. Excavation was made by owner and the construction of reinforced concrete structure was done by main contractor. For execution main contractor hired subcontractors. The data collection was through personal observation and also interviewing the civil engineer supervisors. In addition to the case study, a questionnaire survey was conducted among medium to large size reinforced concrete construction projects. 2 construction projects contributed to this survey.

The results of case study project showed that the rework cost is 1.85% of the construction cost and time delay due to rework is 4.1% of the duration of constructing reinforced concrete structure. By analyzing the data, similar results were determined from the questionnaire survey. Survey results indicated that, about 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 of rework cost was determined as: 46% of contractor, 37% of owner, and 17% of consultant. Cost and time impact of rework items were also examined in this research. For this, importance index of each rework item was calculated. The rework factors of each phase of construction and the total rework items were ranked by their significance in cost and time effect separately. The final results of this study showed that around half of rework cost in constructing reinforced concrete structure caused by contractors. Lack of construction experience, hiring contractors just based on the offered price, lack of coordination between contractor and management team, and lack of adequate supervision resulted in high level of contractor's share in cost of rework.

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