Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.9, No.9, 2017

Cost Evaluation and Management for Adopting Reinforced Earth Retaining Structures in Jordan

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Abstract

Globally, different studies and investigations in the field of new technologies and alternative building materials are continuously performed to decrease the cost and time of carrying out construction projects. In this research, a geotechnical and management investigations were conducted to evaluate (primarily) the cost of adopting reinforced earth retaining structures in Jordan and then to compare this technology with conventional concrete retaining walls. In Jordan, the reinforced earth technique is relatively performed, since 2005; however, it is still not popular among the construction engineering sectors.

The methodology of this research consisted of two stages. The first stage included collecting for literature of previous investigations and the required information related to the above subject; whereas, the second stage focused on the idea of adopting reinforced earth structures for a proposed project in Jordan, then considering it as a case study for this research. Briefly, the study project was a proposed retaining wall that to be executed along one side of an existing road located at Al Fuhais City (about five kilometers from the Capital Amman). Accordingly, a comparison study for implementing two alternatives of retaining structures had been conducted for this project (i.e., reinforced earth & reinforced concrete retaining walls). The engineering evaluation of carrying out this project has been studied during performing a comprehensive analysis for each alternative considering the structural cost, labor and equipment's costs, quality and availability of the required materials, applicability, and the construction management.

Considering the results of this research, it was concluded that conducting reinforced earth retaining structures in Jordan has more benefits considering their lower cost, less duration of execution, the availability of materials, the presence of workers with good experience, in addition to other several factors concerning the structure's durability, and serving as projects with most convenient to local environment.

Keywords: Reinforced Earth Walls, Engineering Management, Cost Evaluation, Planning, R.C Walls.

1. Introduction

To improve the efficiency performance for construction projects, the project managers and civil engineers always seek to execute them within a shortest period, and with the usage of low cost and high-quality materials.

In Jordan, to advance the construction industry, there is a need to introduce the innovative technologies and materials in the Jordanian construction market. To introduce these innovations, the analyses of regulations and requirements of the local labor market and building codes must be considered. In general, the building construction aspects in Jordan are regulated by the National Building Law that comprising thirty-two codes (MWPH, 1993).

This research emphasized on adopting reinforced earth retaining structures in Jordan (i.e. geo-synthetic reinforced soil walls) through conducting comparative analyses with those known as conventional technologies (i.e., reinforced concrete retaining walls), then showing their benefits in the field of construction. In general, the study considered a presentation for several details regarding the design, total cost & duration of execution, and construction management practices at project's sites in Jordan.

It is to be stated that this research had focused on the aspects of engineering project management in terms of evaluation the cost and duration of implementing reinforced earth technology including initial cost, material cost, labors & machines (equipment) costs.

2. Literature Review

Several studies had been carried out by researchers to investigate the planning and management of adopting

retaining earth structures (i.e., reinforced soil walls). However, some of these are summarized below:

McGowan A. (2000) identified the various forms of geogrid reinforced earth walls and described their components. In this paper, the nature of the loads to be supported and the critical deformations developed were presented; following this, the current level of knowledge of the behavior of each structural component and of the overall structure was assessed, then the areas of possible future research related to these types of walls were suggested. In addition, the important role of construction methods was emphasized and the need to develop innovative techniques was identified. Finally, the total cost and environmental benefits of the use of geogrid reinforced earth structures were considered in this paper, and the possibility of gaining a better understanding of this technique was clearly identified and concluded.

Zornberg J. (2007) studied the properties of geosynthetic reinforced soil and its advantages. He focused in this paper on recent advances for the reinforced soil technology, such as advances in the design for conventional and unconventional loadings and other advances in the material (i.e., using geogrid and geotextile). The author carried out an experiment to test the effect of fiber reinforcement on stress-strain behavior and shear strength. Out of the results of this research, it was concluded that when adding more fiber reinforcement, the peak shear was increased with increasing the fiber aspect ratio. In addition, the fiber reinforcement tended to restrain the volume dilation of the soil in drained condition.

Nalawade R. (2008) presented a study related to the stability and cost of reinforced retaining earth techniques in India for conducting roads over bridge projects in India. In this research, they suggested to stabilize the soil by installing tensile reinforcing elements (such as steel strips in the backfill soil). In general, the authors studied the properties of soil and specified it, then studied the stability of soil, bearing capacity, moment and tensile forces that needed in the design, and presented the required designs using two alternatives namely: geogrid retaining walls & metallic strips retaining walls for the study projects. After that, they have studied the total cost for 1-meter square of the bridge for each technique and make a comparison between them. However, this research concluded that the earth wall using geogrid material reduced the cost of carrying out the project up to 32%; whereas, those of metallic strips reduced the cost for about 25%.

Maplesden P. (2016) studied the objectives for the construction project management that needed to be accomplished for the intended project to perform it within a specific time, logic budget, and high-quality performance. Accordingly, the paper concluded that these objectives are:

- Identification for the project and its components.
- Identification for the time, budget, and the scope for the project.
- Establishment for a project plan and schedule.
- Providing regular reports to improve the communication among stakeholders.
- Delivering the specified outputs of the project to the right scope, cost, time, and quality.
- Studying for the risk management planning.
- Managing for project resources.

3. Case Study

As stated before, the case study of this research is a proposed retaining structure (of two alternatives) that to be constructed along one side of an existing road (Princess Tasneem Bint Ghazi Road, from Station 0+540 to Station 0+690 Left Hand Side) located at Al Fuhais City that is approximately 5km north-west of the Capital Amman, see Figure 1. However, at the period of conducting this research, the road was in a process of expansion (i.e., from one-lane two direction carriageway to double-lane two direction carriage way) where the visual description of the existing ground materials that covering the study site were composed of fill materials. In general, the soil and rock layers (existing subsurface materials) at the study site, in addition to some of their engineering parameters that were used in the design of both alternatives is shown in Table 1. Other data related to materials to be provided from out of the site (if required) is shown in Table 2.

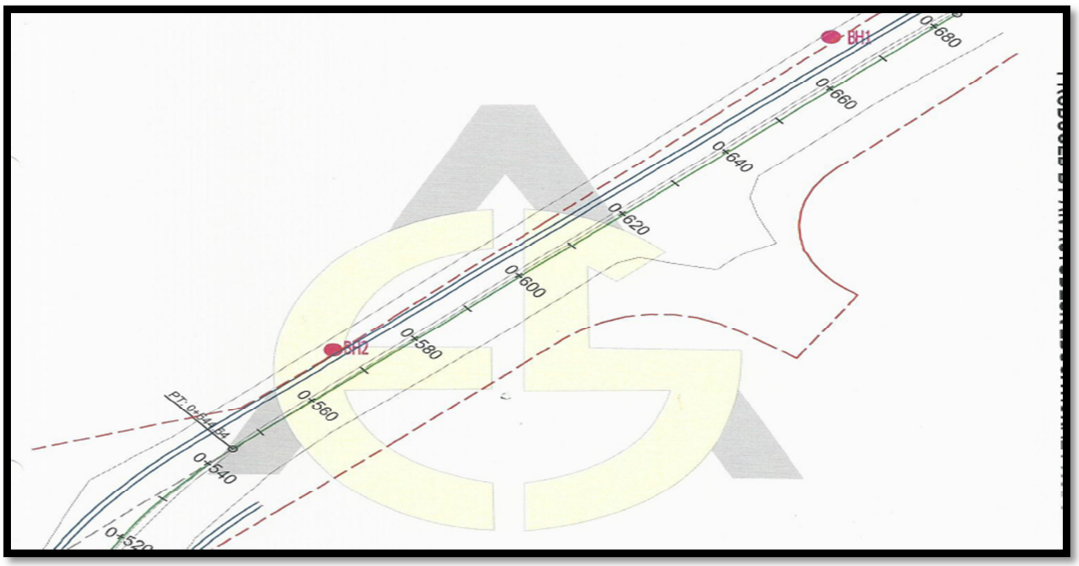

Figure 1. General Site Plan for the Study Project Including the Location of the Proposed Retaining Wall (Provided by: Engineering Axes for Studies, 2013)

Table 1. Existing Subsurface Materials and their Parameters for Earth Pressure Calculations

Material Type	**Unit Weight, kN/m^3**	**Cohesion, kN/m^2**	**Angle of Internal Friction**	**Coefficient of Active Earth Pressure, K_a**	**Coefficient of Passive Earth Pressure, K_p**
Embankment Fill	14	0	14	0.61	1.64
Buried Topsoil	18	10	21	0.47	2.12
Marly Limestone (Proposed Foundation Layer for Walls)	22	38	33	0.29	3.39

(Provided by: Engineering Axes for Studies, 2013)

Table 2. Properties for Selected Fill and Filter Materials and their Parameters

Material Type	**Unit Weight, kN/m^3**	**Cohesion, kN/m^2**	**Angle of Internal Friction**	**Coefficient of Active Earth Pressure, K_a**	**Coefficient of Passive Earth Pressure, K_p**
Selected Fill	20	10	36	0.26	3.0
Filter Materials (Single Size)	16	0	35	0.27	3.69

(Provided by: Engineering Axes for Studies, 2013)

4. General Design of the Proposed Alternatives

Referring to the collected data derived from the conducted site investigation for the study area, and considering a retaining wall with a length of 150m, a height ranging between 2.0 and 5.7m, and the active earth pressure calculations, the general designs of the proposed alternatives had been accomplished using GGU Stability and ProKon Software. However, a general designed section for each alternative is shown in Figures 2 and 3. A

general profile plan for the geo-synthetic (Fortrac) reinforced soil wall (from station 0+540 to station 0+620) is also shown in Figure 4.

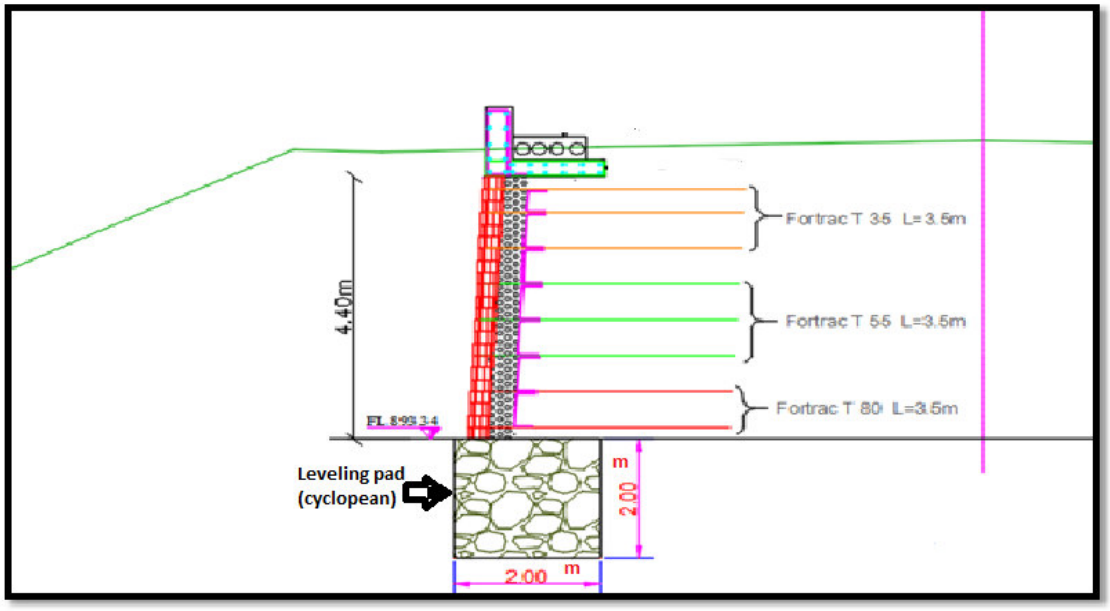

Figure 2. The General Design of the Proposed Geo-Synthetic (Fortrac) Reinforced Soil Wall Using GGU Stability Software

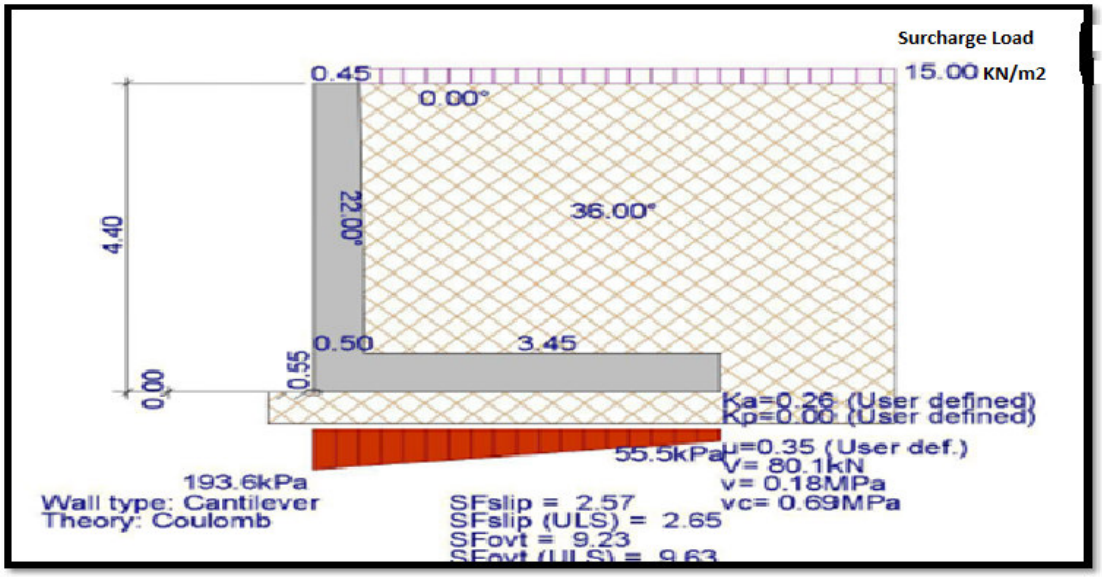

Figure 3. The General Design of the Proposed Reinforced Concrete Retaining Wall Using ProKon Software

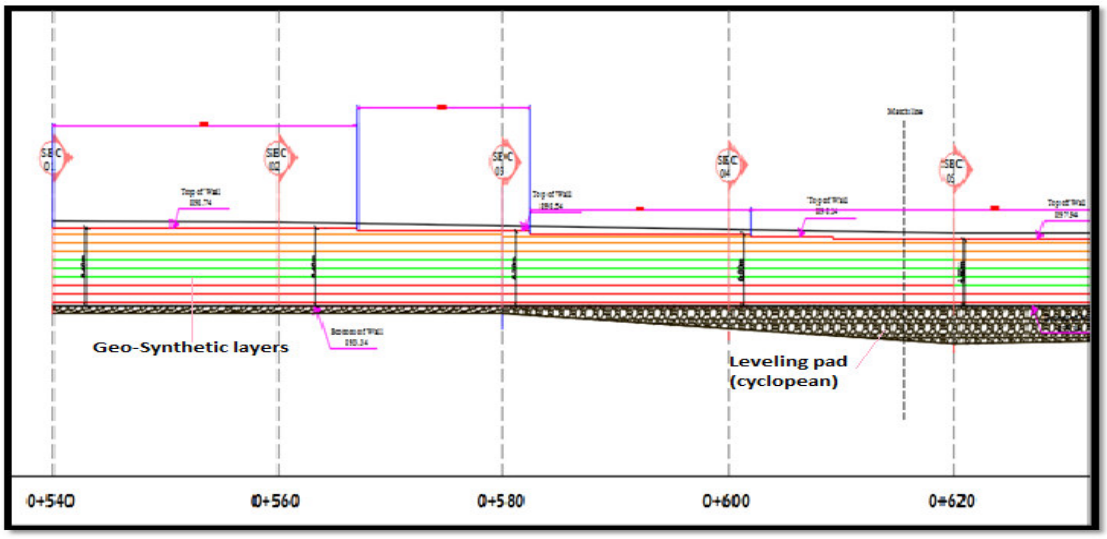

Figure 4. A General Profile Plan for the Geo-Synthetic (Fortrac) Reinforced Soil Wall (from Station 0+540 to Station 0+620)

5. Project Planning

In this research, two engineering plans were suggested to carry out the intended alternatives considering that each of those plans will provide and connect the three components of the project namely: quality of each alternative, the total estimated cost, and the required time for executing the project.

In engineering management, to develop an integrated comprehensive project plan, the project needs to be organized into well-defined pieces of work that can be managed and evaluated. The project manager must be able to develop a written work plan for each project that identifies the work needed to be done, who is going to accomplish it, the time of initiation, and what will the costs be. In addition, the level of details should be adequate to allow for all project participations to comprehend what is expected of them during each phase and duration of the project (PMI, 2008).

In this research, the identification of project activities was initially identified followed by identifying the project plan which was derived from the collected data for different similar implemented projects in Jordan. Therefore, to develop the project plan for a Cantilever Reinforced Concrete Retaining Wall, the activity identification and the time duration was presented (in a sequential manner) in Table 3. Accordingly, the total durations of adopting all activities related to the reinforced concrete retaining wall for the project are found to be 65 working days. On the other hand, all kinds of resources that required for implementing the Reinforced Concrete Retaining Wall, and their costs are indicated in Table 4.

For the Geo-Synthetic (Fortrac) Reinforced Soil Wall, the identification for the required activities and their estimated durations were fixed in a similar way as that mentioned in the first alternative. However, the relevant information was collected from data of more than one executed project in Amman, as shown in Table 5. Accordingly, the total durations of adopting the Geo-Synthetic (Fortrac) Reinforced Soil Wall for the study area are found to be 35 working days. Also, all kinds of resources required to implement the Geo-Synthetic (Fortrac) Reinforced Soil Wall, and their costs are indicated in Table 6.

Table 3. Required Activities and Durations Related to Execute Reinforced Concrete Retaining Wall (from Station 0+540 to Station 0+690)

Activity ID	Activity Name	Activity Duration, Days
A1000	Excavation	12
A1010	Casting for blinding layer (using concrete mixer)	2
A1020	Formwork for foundation (using concrete blocks and cement mortar)	4

Activity ID	Activity Name	Activity Duration, Days
A1030	Steel reinforcement for foundation	5
A1040	Casting concrete for foundation (using ready mix concrete)	1
A1050	Formwork for wall	7
A1060	Steel reinforcement for wall	10
AI070	Casting concrete for the wall (using ready mix concrete)	4
AI080	Removal for formwork, and curing for concrete	14
A1090	Backfilling and compaction	6

Table 4. Costs of Implementing the Reinforced Concrete Retaining Wall (from Station 0+540 to Station 0+690)

Activity ID	Equipment	Equipment Cost, JD	Number of Labors	Labors Cost, JD	Material Amount	Material Cost, JD	Total Cost, JD
A1000	2 Rock breakers + 2 Loaders and 1 Bulldozer	A lump sum of 15680 JD					15680
A1010	Concrete Mixer	100	4	140	61 m^3	4340	4580
A1020	---	---	2	250	150 m^2	900	1150
A1030	---	---	4	560	60 tons	24000	24560
A1040	1 Pumpcrete + 4 Vibrators	100 (for vibrators)	2	100	330 m^3	24750 (including Pumpcrete cost)	24850
A1050	---	---	4	700	1500 m^2	1000	1700
A1060	---	---	4	2100	68 tons	27200	29300
A1070	1 Pumpcrete + 4 Vibrators	100 (for vibrators)	4	560	370 m^3	27750 (including Pumpcrete cost)	28310
A1080	---	---	6	2100	800 m^2	2500	4600
A1090	1 Bulldozer and 2 Compactors	A lump sum of 6300 JD					6300
Total Costs							141030

Table 5. Required Activities and Durations Related to Execute Geo-Synthetic (Fortrac) Reinforced Soil Wall (from Station 0+540 to Station 0+690)

Activity ID	Activity Name	Duration, Days
AIII010	Excavation	12
AIII011	Leveling pad for facing elements	5
AIII012*	Facing elements	9
AIII013*	Geo-Synthetic rolling, Backfilling, and compaction	9

*Considering that these activities will be carried out simultaneously.

Table 6. Costs of Implementing the Geo-Synthetic (Fortrac) Reinforced Soil Wall (from Station 0+540 to Station 0+690)

Activity ID	Equipment	Equipment Cost, JD	Labor	Labor Cost, JD	Material Amount	Material Cost, JD	Total Cost, JD
AIII010	2 Rock breakers + 2 Loaders and 1 Bulldozer	A lump sum of 15680 JD					15680
AIII011, AIII012, and AIII013	A lump sum of providing and carrying out for: cyclopean concrete (leveling pad), facing elements, Geo-Synthetic rolls, backfilling, and compaction for layers				725 m^2 (for the Facing Elements)	72500	72500
Total Costs							88180

6. Results (Comparison Between Alternatives)

It is well known that planning is a decision-making tool aimed at comparing the final cost between projects, and that after calculating the project's duration and determining its total cost.

In this research, the engineering design of the proposed alternatives considered the useful life for each to be approximately equal, and the engineering performance of each alternative is almost the same. In general, when the useful life and performance of the alternatives are equal, then the comparison between them would be primarily depending on the total cost of projects and their duration of construction. A summary of the total cost and duration of each alternative is indicated in Table 7.

On the other hand, during the period of collecting the data required for the design and adoption of the earth retaining structure, it was noticed that materials needed to be used in the construction of the wall are mostly available in Jordan, and the workers who may carry out the different activities related to this technique are relatively available with good execution experience.

It is to be noted that the local regulations for Amman municipality compel the contractor to conduct the required tests for any material to be used in the project through specialized laboratories before being transported to the site (i.e., a quality control for the construction materials); and that means the durability of the used materials will be controlled. If any other influences are stable in the site; the reinforced soil wall technique is regarded as convenient to local environment in Jordan.

Moreover, it is to be stated that during the author's visits to several (old) conducted projects in which the earth retaining technique had been adopted, negligible signs of structure damages or settlements were clearly recognized at those projects.

Table 7. A Summary of the Total Cost and Duration of Executing the Proposed Alternatives

Alternative	Total Cost, JD	Duration of Construction, Days
Reinforced Concrete Wall	141030	65
Geo-Synthetic (Fortrac) Reinforced Soil Wall	88180	35

7. Conclusions

Considering the results of this research, the conclusions are summarized below:

1. Referring to the values of total costs and durations required to perform each proposed alternative, it is concluded that the reinforced earth retaining wall is the most suitable, applicable, and economical alternative.
2. The results emphasized that conducting reinforced earth retaining structures in Jordan has several benefits considering the availability of durable materials, labors with good execution experience, and could be regarded as more convenient to local environments.
3. Performing reinforced earth retaining structures is more practical for road projects compared to other building projects in Jordan, and that is because of this technique may need (relatively) wide space to be conducted.
4. The reinforced earth retaining walls could be used to stabilize relatively high vertical cuts (i.e., with high values of active earth pressure) rather than those for the traditional reinforced concrete walls (in which the height of wall is limited sometimes up to 8m).
5. According to visual inspections for several visited projects (i.e., old performed projects), this type of walls is characterized to be stable for a long period of time with negligible signs of structure damages.

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