International Journal of GEOMATE, Nov., 2020, Vol.19, Issue 75, pp.191-196
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.75.5809
Geotechnique, Construction Materials and Environment

LIFE CYCLE COST ANALYSIS FOR REINFORCED GEOGRID RAILWAY TRACK

*Saad Farhan Ibrahim Alabdullah[1], Ali Jabbar Kadhim [2] and Harith Basim Khalaf [2]

[1]Faculty of Engineering, Isra University, Amman, Jordan;
[2]College of Engineering, Mustansiriyah University, Baghdad, Iraq;

*Corresponding Author, Received: 05 Nov. 2019, Revised: 05 Sept. 2020, Accepted: 25 Sept. 2020

ABSTRACT: The development of railway transportation is facing many challenges, and one of the main challenges is the reduction of track costs. The total cost of railway transportation is derived from construction, maintenance and operation of infrastructure, manufacturing and maintenance of vehicles, as well as fuel production. Since maintenance, costs for the conventional ballasted railway track could be significantly reduced if the developed settlement under loading decreased. The reduction of railway track costs is critical for the competitiveness of railway operators since other competing modes of transportation (e.g. automotive, aviation) have seen a tremendous decrease in life cycle cost in the previous years. In contrast, the prices of railway maintenance have not decreased significantly at the same time. The objective of this study is mainly to focus on the reduction in the railway track cost due to the use of geogrid reinforcement. The results showed a decrease of railway track cost for the sub-ballast reinforced model (4.1%), the ballast reinforced model was (6.5%), and the double reinforced model was (3.73%) as compared to the unreinforced track.

Keywords: Railway, life cycle cost, Geogrid, Reinforcement, maintenance

1. INTRODUCTION

The entire cost of railway transportation comes from construction, repairing, and the operating of facilities, manufacturing, and maintenance of railway vehicles, as well as fuel production. Because maintenance, expenses for the traditional ballasted train track might be significantly decreased if the final settlement below loading is reduced. There are a few current data regarding the lifetime of the actual geosynthetics within the construction associated with the railway. Since the knowledge about using geosynthetics upon railway tracks is only recognised in the past 20 years, and we can claim that the experience, as well as practice from the lifetime of numerous construction techniques, are still not enough to regulate them correctly. Just little estimations available through the geosynthetics manufacturers involving geosynthetics who announced that the materials which they produce might rise the ballast lifetime by 2 - 4 times the original life. Since the deficiency within this data, the computation of repairing and renewal work related to railway tracks had been very few. Additionally, Federici (2003) noticed that the significant available scientific studies on the railway track method that ingest consideration the infrastructures in depth are very hard and mainly focused on car constructions. Consequently, the effect of geogrid support on lowering the cost of the train track will probably be studied [1].

Life cycle cost could be functional for projects through a wide variety of industries that containing railway. Railway track cost has not considerably changed since the past 30 years with comparison to other rival transportation modes [2]. European Commission (2011) on Sustainable Transportation settled goals for the reduction of railway life cycle cost by 30% in 2020. Thus, It is essential to focus on the study of life cycle cost application on railway track [3].

INNOTRACK project used the Geogrid as a part of its numerical simulations and laboratory tests. This approach proved that the geogrid reinforcement would cause a reduction in the life cycle cost and operational disturbances. Hall and Sharpe (2007) used a British Railway case study was done in (1988) where geogrid was introduced for the renewal of railway track in the Derby– Leeds line at Shirland. The railway site was constructed with 300mm of ballast and a 100mm blanketing sand below it, a separation layer composed from a heat bonded geo-textile and a geogrid with a small mesh to stop the particles of ballast from the penetration the geo-textile. A new geogrid having large mesh was furtherly added as a way to support often the soft subgrade. The undertaking condition seemed to be monitored over the long-term performance alongside the operational life of the ballast. The result of monitoring exhibited that the geogrids decreased the requirements of routine maintenance to a tiny proportion of their past level, so reducing the cycle cost [4].

The decision-making, maintenance, and operation costs, without doubt, are significantly more vital than the initial cost of constructions. To achieve overall performance threshold, these types of costs have to be studied all through the lifetime of the project [5]. It is necessary that the making of decisions must be based on the life-cycle foundation. That will be resulted in choosing cheaper strategies within an extended time and cooperated with the available finance. Newest researches concerning railway track improvements with the use of geosynthetics reinforcement indicated a positive effect. The maintenance requirement dropped, and the strength of the ballast was boosted when the geosynthetics were applied. The settlement of the track was 37 to 65 percent less than the settlement of the equivalent portion of the unreinforced test section [6].

The geosynthetics manufacture company Tensar stated that the use of their geosynthetics products would cause a rise in the maintenance cycle three times from its original value after a railway track case study; the railway track was located between London and Scotland. The railway track has been under the speed limit many times although it was maintained frequently two times a year. The intrusion of geogrid in that track caused a considerable decrease in the deterioration rate of the railway track without speed restrictions or maintenance [7].

2. METHODOLOGY

The Life cycle cost (LCC) and the Whole Life Cost (WLC) are well-known methods used to calculate all the related costs with the whole life of design for a specific asset. The Life cycle cost (LCC) and the Whole life cost (WLC) could be used interchangeably while in the (BS ISO 15685-8:2008) international standard for life cycle costing of buildings and constructed specified that the two have different meaning [8]:

- Life cycle cost is well defined, as "is the cost of a part, or its divisions during its cycle life, though accomplishing the performance requirement".
- Whole-life cost is well defined as "is the process of regular economic aspects for the benefits and whole life cost of a known analysis time". Whole life cost covers the extra costs such as Land cost, support cost related to activity in assets, and the incomes produced by the assets. The connection between LCC and WLC is showed in Fig.1.

In order to involve Innovative technology and make appropriate choices on the economic profits of the enhancement works. The life cycle cost and (LCC) should be calculated before and after the use of the technology. The tool was created within the

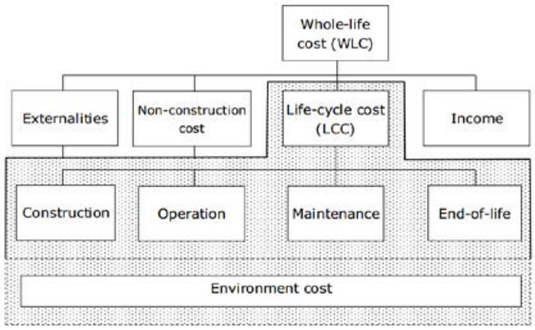


Fig. 1 Scope of life cycle and whole-life costing (Adapted from BS ISO 15685-8:2008).

project SMARTRAIL, and available on smartrail.fehrl.org, was used to validate the cost benefits related to the use of geogrid reinforcement in the railway track system for this research. The smart LCC rail tool was developed by Taking into account the ISO EN 15686-5 standard for LCC.

The following costs were used in the tool:

- Construction costs
  1. The Ballast layer
  2. The Sleepers
  3. Fastening and Rails systems
  4. Elastomeric [Resilient] pads
  5. Geogrid
- Routine maintenance costs:
  1. Stabilisation and Tamping
  2. Milling of rail

Ballasted railway tracks, despite their benefits, present some limitations and drawbacks, mainly associated with geometry degradation due to ballast settlement and particle breakage. Periodic maintenance interventions are thus required as well as renewal processes, which lead to the significant consumption of natural materials and energy while causing frequent interruptions to traffic. Therefore, ballasted railway tracks are considered costly during the maintenance period [9].

Besides, the location of geogrid, which affect the cost of maintenance, was varied to identify an optimum location that yields the best effectiveness in restraining deformations and amount. The following locations should be considered [10]

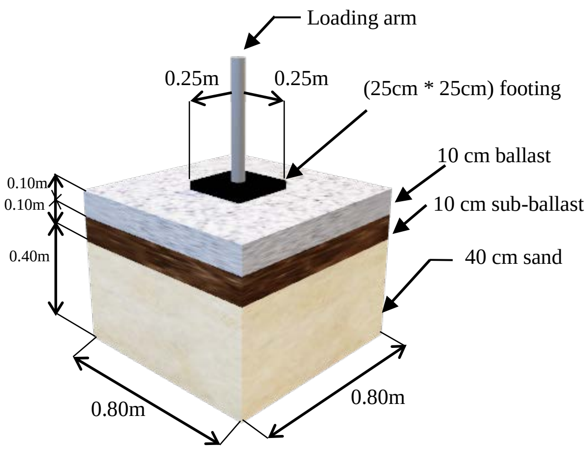
- Interface between subgrade and sub-ballast
- Interface between sub-ballast and ballast
- Middle of ballast and one third from the bottom of the ballast layer

It should be noted that the placement of geogrid between asphalt sub-ballast and ballast layer was omitted since it is deemed unusual to install any

Geosynthetic over asphalt layer, particularly in track roadbed construction.

Geogrid has been increasingly used in railroads to offer reinforcement and confinement pressure to railway track layers. Four models were studied experimentally to measure the difference in the life of the railway track after using the geogrid.

The tested model dimensions were (800*800*600 mm), the subgrade layer was 400 mm, and both ballast and sub-ballast layers were 100 mm thick each. The tested models are unreinforced model, sub ballast-reinforced model, and ballast-reinforced model and double-reinforced model containing a geogrid reinforcement under the ballast layer and sub-ballast layer. The result demonstrated that using the reinforcement layer would reduce the settlement in models. The tested model looks like a sketch in fig.2. Cumulative fig.3 used to show the difference in the result of the settlement between all models that had been tested.



The used tool lets the user discover the effects of different maintenance choices on the life cycle cost of a railway track system. The calculation of life

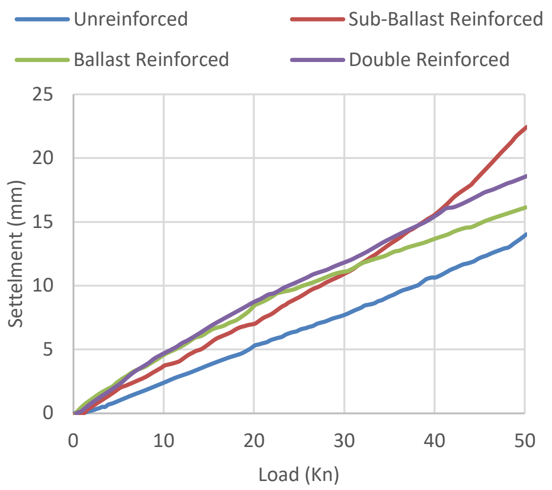


Fig. 3 Load-Settlement relationship for all models at every loading stage

cycle cost is a way to estimate the overall costs of maintaining an asset with a specified period for analysis, to be used as an input into a decision-making procedure. The costs in the future and discounting rate were transformed to be Net Present Value (NPV) to make the judgment simpler in maintenances regimes from a total cost point of view in the present day.

The input data was collected from the "Transportation & Telecommunications of Iraq" report by the United Nations World Bank and the "Hajama – Sawa" Railway Project done by the Iraqi Ministry of Transportation Republic Railways Company [9]. The project life span was assumed would be 60 years. The use of geogrid lead to difficulty of predicting the increase in the ballast lifetime, hence several scenarios were tested, and all of them show the use of the geogrid in the railway track, which will be more economical at the end. Besides. The user data for evaluated models are shown in tables (1) (2) (3) (4) accordingly.

Table 1 The input data for the unreinforced model

Remediation						
No	Name	Description	Cost (€ per km)	First-year	Expected life (year)	Last year
1	Ballast	Replace ballast at end-of-life	€ 771,105.00	0	25	60
2	Sleepers	Replace sleepers at end-of-life	€ 396,185.00	0	20	60
3	Rails and fastening system	Replace rails and fastening at end-of-life	€ 594,278.00	0	30	60
4	Elastomeric pads	Replace elastomeric pads at end-of-life	€ 517.00	0	30	60
Routine maintenance						
No	Name	Description	Cost (€ per km)	First-year	Average Frequency	Last year
1	Ballast tamping and stabiliser	Routine maintenance	€ 1,107.00	0	0.75	60
2	Rail milling	Routine maintenance	€ 5,813.00	0	0.75	60

Table 2 The input data for the sub-ballast reinforced track (Variant A)

Remediation						
No	Name	Description	Cost (€ per km)	First-year	Expected life (year)	Last year
1	Ballast	Replace ballast at end-of-life	€ 771,105.00	0	30	60
2	Sleepers	Replace sleepers at end-of-life	€ 396,185.00	0	20	60
3	Rails and fastening system	Replace rails and fastening at end-of-life	€ 594,278.00	0	30	60
4	Elastomeric pads	Replace elastomeric pads at end-of-life	€ 517.00	0	30	60
5	Geocomposite membrane	Replace membrane at end-of-life	€ 20,000.00	0	35	60
Routine maintenance						
No	Name	Description	Cost (€ per km)	First-year	Average Frequency	Last year
1	Ballast tamping and stabiliser	Routine maintenance	€ 1,107.00	0	0.75	60
2	Rail milling	Routine maintenance	€ 5,813.00	0	0.25	60

Table 3 The input data for ballast reinforced track (Variant B)

Remediation						
No	Name	Description	Cost (€ per km)	First-year	Expected life (year)	Last year
1	Ballast	Replace ballast at end-of-life	€ 771,105.00	0	32	60
2	Sleepers	Replace sleepers at end-of-life	€ 396,185.00	0	20	60
3	Rails and fastening system	Replace rails and fastening at end-of-life	€ 594,278.00	0	30	60
4	Elastomeric pads	Replace elastomeric pads at end-of-life	€ 517.00	0	30	60
5	Geocomposite membrane	Replace membrane at end-of-life	€ 20,000.00	0	35	60
Routine maintenance						
No	Name	Description	Cost (€ per km)	First-year	Average Frequency (per year)	Last year
1	Ballast tamping and stabilizer	Routine maintenance	€ 1,107.00	0	0.75	60
2	Rail milling	Routine maintenance	€ 5,813.00	0	0.25	60

Table 4 The input data for the double reinforced track (Variant C)

Remediation						
No	Name	Description	Cost (€ per km)	First-year	Expected life (year)	Last year
1	Ballast	Replace ballast at end-of-life	€ 771,105.00	0	35	60
2	Sleepers	Replace sleepers at end-of-life	€ 396,185.00	0	20	60
3	Rails and fastening system	Replace rails and fastening at end-of-life	€ 594,278.00	0	30	60
4	Elastomeric pads	Replace elastomeric pads at end-of-life	€ 517.00	0	30	60
5	Geocomposite membrane	Replace membrane at end-of-life	€ 40,000.00	0	35	60
Routine maintenance						
No	Name	Description	Cost (€ per km)	First-year	Average Frequency (per year)	Last year
1	Ballast tamping and stabiliser	Routine maintenance	€ 1,107.00	0	0.75	60
2	Rail milling	Routine maintenance	€ 5,813.00	0	0.25	60

3. RESULTS

Life cycle cost analyses showed a provision economically towards the choice of using geogrid under the railway track, as shown in fig.4. That has been confirmed for all the models that have been tested. Hence, the lifetime is increasing from the use of the geogrid; consequently, this directed us to a situation that the use of the geogrid reinforcement into the railway track layers was cheaper and extra profitable. The expenses differences for the three variants and baseline variant for the railway track is shown in the net present value of the three variants is lesser than that of the baseline although the initial cost is higher; rising from a significantly lesser rate of maintenances.

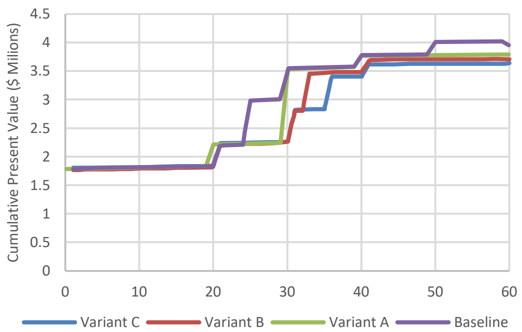


Fig.4 The Cumulative Present Value and time relationship where
Baseline: Unreinforced,
Variant A: The sub-ballast reinforced
Variant B: ballast reinforced
Variant C: double reinforced

It is found that the used method is the most reasonable methods compared with the others while the use of geogrids (for subgrade stiffening) is relatively reliable when used in combination with ground improvements. The adverse climate has also played a significant role in all of the methods. However, it was found that sustainable methods, which are less sensitive to extreme climate, are associated with the applications of geogrid materials such as geogrids, composites.

4. CONCLUSION

Ballasted railway tracks, despite their benefits, present some limitations and drawbacks, mainly associated with geometry degradation due to ballast settlement and particle breakage. Periodic maintenance interventions are thus required as well as renewal processes, which lead to the significant consumption of natural materials and energy while causing frequent interruptions to traffic. The economic evolution indicated that the use of geogrid proved to be feasible and cost-effective in reducing the intervals of maintenance of railway track. Despite slightly higher initial construction cost of railway track when the geogrid used, the lifetime cost will be significantly reduced As the ballast reinforced was the most effective in the reduction of total cost by(6.5%)and the sub-ballast reinforced was (4.1%), and the double reinforced was (3.73%) as compared to the unreinforced track. Significant increase in the demand for freight and passenger transports by trains pushes the railway authorities and train companies to increase the speed, the axle load and the number of train carriages/wagons. All of these actions increase ground-borne noise and vibrations that negatively affect people who work, stay, or reside nearby the railway lines. In order to mitigate these phenomena, many techniques have been developed and studied. Furthermore, there is a severe lack of life-cycle information regarding such methods in order to make a well-informed and sustainable decision. This study aims to evaluate the life-cycle performance of mitigation methods that can enhance sustainability and efficacy in the railway industry.

5. REFERENCES

[1] Federici, M., S. Ulgiati, D. Verdesca, and R. Basosi (2003). "Efficiency and sustainability indicators for passenger and commodities transportation systems. The case of Siena, Italy." Ecological Indicators 3: 155-169.

[2] Paulsson B, Platzer M and Ekberg A (2006) "INNOTRACK – Innovative Track System – A unique approach of infrastructure managers and competitive track supply industry for developing the innovative products of the future", 7th World Congress on Railway Research. pp.1 - 12

[3] European Commission (2011) "White Paper: Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system". pp.10 - 32

[4] Hall C D and Sharpe P (2007) "Review of geogrid stabilization of railway ballast with reference to performance and durability". pp.101 - 106

[5] European Commission (2013) "Sustainable steel-composite bridges in built environment (SBRI)", Final Report. pp.33 - 67

[6] Parsons R., Jowkar M., Han J., 2012. Performance of Geogrid Reinforced Ballast under Dynamic Loading. Report # MATC-KU: 363, Final Report.

[7] Tensar (2013) "Railways: Mechanical stabilization of track ballast and sub ballast", March 2013, Issue 11. pp.924 – 934.
[8] British Standards Institution (2008) BS ISO 15685-8:2008, Buildings and constructed assets – Service life planning – Part 5: Life cycle costing.
[9] Project "Hajama – Sawa", cost estimate, Ministry of Transportation of Iraq, Iraqi Republic Railways Company.
[10] Alabdullah, S.F.I, Taresh N.(2017), Evaluation Of Soil Reinforced With Geogrid in Subgrade Layer Using Finite Element Techniques International Journal of GEOMATE, July 2017, Vol.13, Issue 35, pp.174 - 179