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# A Life Cycle Cost Analysis Model for FRP Bridge Deck



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***In The Name of God***

Abstract

# A Life Cycle Cost Analysis Model for FRP Bridge Deck

**In this thesis, a prototype life cycle cost-estimating method for FRP bridge decks has been developed. The model considers the agency costs, user costs and the third party costs to establish the life cycle cost of an FRP bridge deck. The model features two condition indices for maintenance ($CI_M$) and for repair ($CI_R$) that can estimate the condition of the bridge deck in any given year. Based on the limiting values set on the indices, a decision for maintenance and repair is made when the index value for a year exceeds the limiting value. The user can enter these limiting values. Two kinds of repair strategies are considered; one putting an overlay on the bridge deck and the other is replacing the deck. Based on the repair strategy selected, both the condition indices are reduced to represent the improvement in the quality of the bridge deck.**

**The model also features a sensitivity analysis of the Life Cycle cost of the bridge deck, which compares certain specific input parameters. The primary goal of the sensitivity analysis is to be able to understand the effect of some of the input parameters on the life cycle cost of the FRP bridge deck.**

**The life cycle cost estimation model developed in this thesis can be used as a basic tool to evaluate the use of fiber reinforced polymers (FRP) for constructing bridge decks against other conventional materials. The model generates an estimate of the life cycle cost of an FRP bridge deck and the cost values can be compared with the life cycle cost values of bridge decks made with conventional materials**

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# 1. Introduction

**Highway bridges have been built from two typical construction materials: steel-reinforced concrete and structural steel. Both materials decay in predictable ways, and bridges made from them deteriorate to a level where the structures must be rehabilitated or replaced. The cost of such rehabilitation or replacement of these bridges is very high with the cost being close to approximately $2 million to $8 million per bridge[1]. There has been a growing concern among the officials of highway administration sections all over the world regarding the high bridge rehabilitation costs. This is resulting in pressures on the state and private transportation agencies to find new materials and designs that would substantially reduce the overall life cycle costs of bridges and also increase their service life.**

**Therefore, many alternative materials are currently being developed for bridges and bridge components. High performance concrete, high performance steel, aluminum, fiber-reinforced polymer (FRP) composites, and FRP-reinforced timber are some of the new construction materials being used for bridge and bridge components.**

**These materials usually have some type of qualitative performance advantage over conventional materials. For example, high performance concrete has higher strength and is more impervious to road salt intrusions than conventional concrete. FRP composites require designers to create unique and structural shapes to meet strength and deflection requirements. The light structures also contribute to the ease of installation, in which they can be installed by hand instead of by cranes. Aluminum bridge elements are light and can be easily recycled. FRP timber**

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[1] Lopez-Anido, R. 2001. **"Life-Cycle Cost Survey of Concrete Bridge Decks - A Benchmark for FRP Bridge Deck Replacement."** TRB ID Number:01-3166; Transportation Research Board 80th Annual Meeting; Washington, DC; January 2001

**components are light, are aesthetic, can be portable and are generally low cost but they do not have high strength and durability[2].**

**New construction materials for bridge decks must be selected with great care and foresight over the conventional construction materials. Some minimum technical criteria must be first satisfied, such as the material's ultimate strength, stiffness and expected life of the structure under a set of defined environmental conditions. If these criteria are satisfied, the most important issue becomes the cost issue-that is the Life Cycle Cost. Mandates from Government bodies require project planners to consider the costs of a proposed project (such as a bridge) over its entire life span (i. e. its life cycle costs).**

**LCCA is defined as "a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future cost, such as maintenance, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment"[3].**

**The basic intent of requiring LCCA on higher-cost bridge projects is to "reduce long-term costs and improve quality and performance"[4].**

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[2] Market Development Alliance of the FRP Composites Industry; [http://www.mdacomposites.org/Why_FRP.html]

[3] [ http://www. fhwa. dot. gov/legsregs/directives/policy/lcca. Htm]

[4] Nathan, T.R. ; Onyyemelukwe, O.U " **Comparison of bridge deck alternatives using life cycle costs**" , 8th ASCE Specialty on Probabilistic Mechanics and Structural Reliability

## 1.1 Economic Consideration and Life Cycle Cost Analysis

**Many alternative materials have not been used in a widespread manner mainly due to high initial costs. Bridge project managers still detest high up front or high initial costs, especially when the life cycle costs of a relatively new material are unknown. To overcome this initial cost differential between the new materials and the conventional materials, a practical and economic method for evaluating alternative materials in a comprehensive and consistent manner is needed, like the Life Cycle Cost Analysis[5].**

**LCCA is a means of assessing the total cost of facility ownership. It involves translating all expenses associated with a structure ownership over a prescribed "life cycle" period into a desired currency unit. These include initial construction cost, operating outlays, maintenance, repair and replacement expenditures, and the further breakdown of these costs into the user costs, agency costs and the third party costs.**

**The steps involved in the life cycle costing and selecting the most viable alternative from amongst these "new" construction materials is as follows:**

1. **The project objective and the minimum performance requirements of the structure must be defined. The design of a project that has a new technology material must often be based on a performance design code instead of a prescriptive design code since most new-technology materials lack a specific prescriptive code. "The foremost performance code requirement in the FRP bridge deck analysis is that the bridge be**

[5] Lopez-Anido, R. 2001. **"Life-Cycle Cost Survey of Concrete Bridge Decks - A Benchmark for FRP Bridge Deck Replacement."** TRB ID Number:01-3166; Transportation Research Board 80th Annual Meeting; Washington, DC; January 2001

**able to carry AASHTO HS-20 loads and that its deflection not exceed specific maximum span deflections under such loading[6].**

**2. All the alternative materials that satisfy the project target and performance requirements should be identified.**

**3. The basic assumptions of the costing process must be established. These assumptions include specification of the base year for the analysis, the life cycle study period, the real discount rate and the inflation rate.**

**4. All the costs that occur during the lifetime of the structure must be identified, classified and estimated.**

**5. The life cycle cost of each alternative should be computed.**

**6. A risk assessment model should be evaluated for the total LCC calculated.**

**7. Sensitivity analysis by computing the LCC for each alternative materials using different data inputs that are both relatively uncertain and significant should be performed**

**8. Life cycle costs of each of the alternatives should be compared.**

**9. The best alternative should be selected. The alternative with the minimum LCC should be selected.**

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[6] Ehlen, Mark A. & Marshall, Harold E. "**The Economics of New-Technology Materials: A Case Study of FRP Bridge Decking**", July 1996, Building & Fire Research Laboratory, National Institue of Standards and Technology.