Design and Analysis of Highway Bridge based on their Material and its Comparative Study of Life Cycle and Cost Analysis

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Abstract - *Sustainable development has gained increasing interest in the bridge industry in the recent years, with special regard to economic and environmental impacts. In line with this, holistic approaches considering all costs and environmental impacts in a life-cycle perspective are needed. Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. These factors affect the conceptualization stage of design. A conventional concrete bridge deck and an alternative engineered cementations composite link slab design are examined. Despite higher initial costs and greater material related environmental impacts on a per mass basis, the link slab design results in lower life-cycle costs and reduced environmental impacts when evaluated over the entire life cycle. We also compare the cost of PC Bridge and steel Bridge and their cost. These results show life-cycle modeling is an important decision-making tool since initial costs and agency costs are not illustrative of total life-cycle costs. Additionally, accounting for construction-related traffic delay is vital to assessing the total economic cost and environmental impact of infrastructure design decisions*.

***Key Words*: Life cycle cost, IRC Class loading, PC Bridge, Steel Bridge painted, Steel Bridge Galvanized, STAADPRO Software**

1.INTRODUCTION

The bridges are the structure which provides means of communication passage over a gap. In some gaps, the water flow for a part of the year or whole of the year. Whereas, some other gaps remain dry throughout the year. The rivers, canyon's and valley form natural gap. The highway crossings, highway and canal crossings form artificial gaps. The bridges provide passage for the vehicular or other traffic over these gaps. The bridges constructed to carry highway traffic are known as Highway Bridges. The bridges are made of Timber, Stone masonry, Brick masonry, Reinforced cement concrete, Prestressed cement concrete and Steel. Bridges obviously serve multiple functions but the primary purpose is to traverse a terrain obstacle to get goods or people across to the other side. Bridges are often viewed as an indicator of progress in technical capability, engineering skills as well as a symbol of economic potential of a particular city, region or a country. Often, this is the reason why many urban bridges become the most important infrastructure in some cities. Planning and designing of bridges is part art and part compromise, the most significant aspect of structural engineering. Along with this, comes the substantial amount of specifications that must be abided by, a majority of which are outlined in the IRC Bridge Design Specifications IS Standard and, before we began to design, we were required to first analyze the bridge conceptually. Defining the basic parameters of the bridge then, allowed us to begin to define its function and performance. In doing this it was important to constantly consider the solution to safety while minimizing cost. In this conceptual analysis we took both an analytical and practical approach which incorporates both new and old methods. This preliminary analysis aids in creating the final design while reducing the overall design efforts.

1.1 Objectives

- Determine the achievable useful life for a bridge.
- Determine the life-cycle cost of a bridge.
- Formulate a cost model for bridge life-cycle cost.
- Determine the design practice that leads to the lowest bridge life-cycle cost.
- Determine the maintenance and rehabilitation practice that leads to the lowest bridge life-cycle cost.

2. LITERATURE SURVEY

Andrzej Niemierko [1] studied Structural bearings is a basic act intention of which is providing a good manufacturing quality and operation of modern bridge bearings. It has influence on durability and reliability of bridge expansion joints which are often complex mechanical structures. Modern bridge bearings and expansion joints are at present rather mechanical structures but not construction ones as they were treated previously. A bearing is an element of a bridge structure which determines the durability and reliability as well as its safety behavior. In the middle of last century many innovative bearing designs were invented. They are nowadays very popular in bridge engineering.

Cathal Leahy, Eugene Obrien [2] studied Freight traffic in the European Union is increasing with time. He describes a method for considering this growth when assessing traffic loading on bridges and examines the effect of this growth on characteristic load effects. The Eurocode Load Model 1 is used for the design of new bridges. As this model can be overly conservative for the assessment of existing bridges, a scaled down version can be used by applying α-factors to the load model. This is usually done by modelling the traffic loading on the bridge using site-specific weigh-in-motion data and calculating the α-factors in accordance with the results.

Dr. Saleem Akhtar, Mayank Chourasia [3] studied the design of a highway bridge is critically dependent on standard norms of a particular region or country and criteria like loadings and support conditions. Naturally, the importance of highway bridges in a modern transportation system would imply a set of rigorous design specifications to ensure the safety, quality and overall cost of the project. they were discusses the parametric study of two different cross-sections of box-girder for same loading conditions to find the most economical cross-section. The design standard of India, IRC was followed in design of Box-girder superstructures subjected to IRC class AA loading. Optimized Cross-sections was found by comparing the different design parameters.

Hellon G.Ogallo, Manoj K. Jha [4] studied Sustainability and green transportation initiatives have been widely promoted in highway design and maintenance in recent years. While there are many definitions of sustainability and green transportation, there has mainly been a qualitative description of such initiatives in previous works. In this we propose a quantitative analysis of sustainability and green transportation from highway design and maintenance perspective. There is a considerable interaction between highway design and maintenance.

In **yoman Sutarja, Ida Bagus Rai Widiarsa [5]** studied Steel truss bridges with continuous reinforced concrete slab as vehicle decks are often found in Indonesia. The use of continuous reinforced concrete slab along the steel truss bridges has still have some problems in the field such as the occurrence of cracks. Cracks that occur on the concrete slab are required to be repaired, which is mostly done by grouting method. However, the method are still unsuccessful in addition to costly expensive. Study on partial prestressed concrete slab as vehicle decks of steel truss bridge was done. The system used was a partial prestressed concrete segmental slab in one direction which was set transversely the bridge.

J.Studnicka, S.Thondel [6] studied Steel-concrete composite structures are structures that combine the advantages of both used materials. An advantage of such structures is their high bending resistance, which has a positive effect on the overall weight of the structure. The disadvantage could otherwise be a slightly complicated design of individual elements. They describes an experiment with two simply supported 6 m long steel-concrete composite beams loaded in their thirds. The each beam is made of standard steel rolled profile and concrete slab concreted into the transversally oriented trapezoidal metal sheet with rib height equal to 135 mm, although European standard restricts the rib height only to 80 mm for common use. The research is focused mainly on deflection of beam, whether partial or full shear connected and also deals with the possibility of modeling these structures using the finite elements method. The shear resistance of stud in narrow and wide concrete rib is investigated too.

Khairmode A. S. , Kulkarni D. B.[7] Prestressed concrete structures are widely used in all over the world. They give better performance with smaller cross sections. The prestressed concrete construction is more suitable for medium and long span bridges with heavy loads. Now the prestressed concrete system is also used in curved bridge with long span. It has become challenge to analyze this bridge deck due to geometric complexities and interaction between bending and torsion. In this the analysis of horizontally curved prestressed concrete box girder bridge deck is studied by using three dimensional modeling and analysis. Section geometry, material properties and radius of curvature are same in all the models while angle of curvature is varying from 0° to 90° and angle of curvature are kept constant as 30°,60° and 90° and its radius of curvature varying from 25 m to 50m.Analysis is carried out using the IRC Class AA loading.

Klaudiusz Fross, Marek Salamaka [8] Bridges obviously serve multiple functions but the primary purpose is to traverse a terrain obstacle to get goods or people across to the other side. Bridges are often viewed as an indicator of progress in technical capability, engineering skills as well as a symbol of economic potential of a particular city, region or a country. Often, this is the reason why many urban bridges become the most important infrastructure in some cities.

They discuss several examples of bridges which have made a significant impact on the perception of a city and resulted in substantial changes to landscape configuration. A typical urban bridge, in comparison to a highway bridge, also serves pedestrian traffic and therefore must satisfy additional safety and comfort conditions.

3. RESEARCH METHODOLOGY

3.1 Life cycle cost of bridge:

The life-cycle of a bridge is a reasonable amount of maintenance and intermittent rehabilitation and replacement work. Most maintenance work is handled by a local governing agency. This agency also undertakes a great deal of the rehabilitation projects, with minor contributions from outside design and construction firms. On the contrary, an agency will outsource just about any work associated with either the replacement of an individual element or the entire bridge structure. In considering the costs for future maintenance work we often have to consider, the type of material, condition, location, average daily traffic, highway classification, etc. The costs associated with the rehabilitation of bridge elements should be estimated for different types of elements and the different rehabilitation alternatives applicable for each element type. Element replacement costs are to be estimated the same way as rehabilitation costs but are a separate entity as they may receive a different source of funding.

A comprehensive assessment of the economic efficiency of bridges rehabilitation projects, as it was already stated is only possible by applying various methods of economic CBA indicators. Cost-benefit analysis of the project can be carried out as an economic (if the project realization will never serve public purposes) or financial (if the building generates revenues). The economic Cost Benefit Analysis is, as already mentioned, economic method, which has the economic indicators that allow assessing the economic effects of the construction project, its rate respectively. In the next section of this chapter, there are summarized in the general shape the economic indicators applied to the needs of the bridge's rehabilitation projects. Though life-cycle costing is not a straight forward procedure it is important to integrate into the design process as it provides the ability to quantify inconspicuous details in ensuring a sustainable financial system is in place for the life of a bridge.

3.2 Life cycle cost analysis:

A life-cycle cost analysis has different steps to identify a design for our recommendation. The first step to complete this process was gathering the necessary information. This information included the period and cost for various maintenance, repair and decommissioning activities during the life of the structure. These activities include repaving, inspection, painting, non-destructive testing, rehabilitation, demolition, and salvage. We used the initial costs that were determined in our cost estimate as base costs. A yearly maintenance cost was determined for each of the designs also included. The second is to obtain Life-Cycle Analysis spreadsheet and then insert all design variations into sheet. Design variations consist of steel, concrete and spacings. The 3rd step is applying all life cycle conditions and all considerations and last step is compiling all three steps and get results. The life-cycle cost analysis an important technique for assisting with investment decisions. In the world of transportation, bridges have a much longer lifespan than pavements, making them a long-term investment. In an effort to ensure the success of these investments, a system is instituted which considers both agency and user costs. Agency costs are reduced through the aid of the lifecycle cost analysis which provides investment planning to ensure needed funding is available each year. In order to adequately conduct a life-cycle analysis, we account for all potential elements related to cost including the governing agencies responsible for each entity. Additionally, user costs are considered to produce a well-rounded result, incorporating often overlooked factors which can place a financial burden on non-agency affiliated personal.

3.3 Staad Pro Software

Pro Software is being widely used for the analysis and design of buildings, towers etc. In this project, STAAD Pro. has been used for the analysis and design of a deck slab bridge in connection with STAAD beava. It becomes much easier to assign the properties and other specifications in creating deck slab by the STAAD Pro. software. The various properties are to be considered in the analysis and design of the deck slab of a bridge which include section property, plate thickness, dead load, live load etc. Dead Load consists of its own weight and portion of weight of superstructure and fixed loads also. Live loads are caused by vehicle moving over the bridge Live loads have four types of standard loadings for which the road bridges are designed. These include and we also used

(i) IRC Class 70R Loading (ii) IRC Class AA Loading (iii) IRC Class A Loading (iv) IRC Class B Loading

(i) **IRC Class 70R Loading** is applied for permanent bridges and culverts. Bridges designed for this type of loading is checked for Class A loading.

(ii) **IRC Class AA Loading** is adopted within municipal limits for existing and industrial areas.

(iii) **IRC Class A loading** is adopted for all roads on which permanent bridges and culverts are to be constructed.

(iv) **IRC Class B loading** is adopted for timber bridges. Here the model is being designed as per IRC 70R loading which is applicable on all roads on which the permanent bridges and culverts can be constructed. Analysis and Design process by STAAD Pro determines the performance of Structures. The designing by the software saves the design time and by this way we can check the safety of the structure very easily.

4. RESULTS AND DISCUSSIONS

The overall bridge having four different traffic lanes and each lane having some own parameters, the detail description of each lane is below.

The loading vehicle details are given: Design Code = IRC
Loading Class = Class 70R Loading Max.
Effect = 9.39626m
Unit of Length = m
Unit of Force = kN
Combination Factor =1
No. of Traffic Lanes = 4
Traffic Lane number 1
Lane Factor = 1
The loading vehicle details are Width = 4000
Front Clearance = 31675
Rear Clearance = 31675
No. of Axles = 3

Table 1: Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	17.171	0.05	0

End Lane

Traffic Lane No. 3 Lane Factor 1 The loading Table 3 : LCC Comparisons of PC and Steel Bridges
vehicle details are Width = 4000 Front Clearance = 31675
Rear Clearance = 31675 No. of Axles = 3

Table 2: Vehicles travel in the roadway direction

Vehicle No.	Position x	Position y	Orientation
1	11.9501	88.219	1.5708
2	11.9501	49.689	1.5708
3	12.05	-4.35305	1.5708

Table 3: Calculation of Cost Analysis

	PC Bridge	**Steel bridge (painted)**	**Steel bridge (galvanized)**
New Construction cost	1,295,980,460	1,810,945,319	1,934,623,319
Preventive maintenance cost	141,933,750	293,814,300	202,910,970
Repair & Replacement cost	1,178,661,344	831,459,307	831,459,307
Demolish cost	47,865,600	73,236,900	73,236,900
Recycle benefit	0	-103,065,000	-103,065,000
Life cycle cost	2,664,441,154	2,906,390,826	2,939,165,496

5. CONCLUSIONS

This research an overview of the different components of which an overpass consists, in a top-down manner. An overview of the considerations of construction and life-cycle cost analysis is discussed in addition to overall bridge design, pertaining to IS Standard and IRC specifications, necessary analyses, and limit state concepts. The total life-cycle cost of pre-stressed concrete bridge is around 2.664 billion. Steel bridge (painted) is roughly 2.906 billion. The steel bridge (galvanized) is roughly 2.939 billion. In the aspect of economy concern, the case with the lowest life-cycle cost still belongs to pre-stressed concrete bridge. Table 10 is the integrated comparisons among each case of the life-cycle cost.

This research, by the help of sensitivity analysis of other influential factors, understands the importance of each influential factor on the bridge life cycle cost.

1. It can be understood from the sensitivity analysis of galvanizing service life that, if the service life of galvanizing can reach over 40 years, the life-cycle cost from steel bridge (galvanized) is lower than the steel bridge (painted) one. However, it should be considered if the geographical environment of the bridge location is suitable. Moreover, the uncertain risk should also be considered. Pre-stressed concrete bridge is still the most economic case among all.

2. Sensitivity analysis of the market price of steel indicates that although the fluctuation of market price influences the total life-cycle cost, it does not affect the selection of cases. Pre-stressed concrete bridge is still the most economic case, similar as the other sensitivity analysis case.

Combining the above statements, the construction cost within the bridge life-cycle costs is the first priority. Nevertheless, there are many factors influencing bridges, such as impact of environment, landscape, risk cost and social cost, but, due to the various uncertain factors, there are not relative quantification researches in Taiwan and abroad. Therefore, this research calculates and analyzes by the method of life-cycle cost, which can quantify information.

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