BRIDGES ECONOMICAL EFFICIENCY

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Abstract

A bridge is a structure built to span physical obstacles such as a body of water, valley, or road, for the purpose of providing passage over the obstacles. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed, the material used to make it and the funds available to build. Bridges can be used as crossing works afferent to forest roads and that constitute an important element of forest roads execution cost. Their construction involves ecological, social and economical terms. For this consideration, materials shall be selected on the basis of sustainability, economy, aesthetics and durability.

Key words: bridge, economics, cost, concrete, timber, culvert.

INTRODUCTION

Whether a bridge installation is required or not depends on the bridge's structural and economic efficiency. Engineers and transportation planners consider these two factors to determine whether a bridge should be installed, as well as how to improve a standing bridge. Structural efficiency refers to the bridge's ratio of load (how much weight will be carried by the structure) to physical mass. Economic efficiency considers how much money and resources are saved by having a bridge, compared against the bridge's total cost.

CONCRETE BRIDGES

In the last three decades, the use of high performance concrete (HPC) incorporating supplementary cementing materials (SCMs) in concrete structures has increased considerably. The use of HPC enables the construction of structures with higher strength, lower weight and longer service life than normal performance concrete (NPC).

The initial cost of structures built using HPC can be much higher than those built with NPC. However, HPC structures have much longer service lives than NPC structures, which in turn lead to lower maintenance and rehabilitation costs over their life cycles. The selection of cost-effective design and rehabilitation alternatives should therefore be based on the total life cost of the structure, which includes the initial construction cost and the costs of inspection, maintenance, rehabilitation, and replacement.

A realistic approach to life cycle analysis should consider all the key stages, which includes extraction and transportation of the raw materials, construction, maintenance, repair and rehabilitation, replacement, and disposal of the structure. Different types of costs are incurred within the life cycle of a structure, which can be divided into different categories, including owner's costs, users' (or social) costs, and additional third-party costs (e.g. environmental costs).

A comparative life cycle assessment of the performance, cost and environmental impacts of high performance (HPC) and normal performance concrete (NPC) is sometimes undertaken of reinforced concrete highway bridge decks that are built in corrosive environments. The determination of the deck service life is required for the life cycle cost analysis and life cycle environmental impact assessment.

The direct costs incurred by the bridge owner include the initial construction costs and costs associated with the inspection, repair, rehabilitation and replacement. The initial construction costs include the in-place costs of concrete and reinforcing steel and additional construction costs.

The in-place costs include, in addition to the on-site material cost, the cost of formwork, placing the reinforcement steel, pouring and surface finishing of the concrete, and form stripping.

The estimated in-place cost of HPC with SCMs will depend on factors such as: the cost of different SCMs varies widely. Depending on the location of the construction site, the cost of silica fume may be 3 to 5 times higher than Portland cement Type 10, whereas the costs of slag and fly ash vary between 40% and 85% of the cost of Type 10 cement; additional cost for incorporating SCMs in concrete mix; additional storage space for SCMs.

The cost of patch repairs includes: cost of removing the contaminated or deteriorated concrete; cost of concrete patching; cost of traffic control when the bridge is partially opened to traffic.

It is assumed that 5% of the deck area is usually repaired at each occurrence of the patch repair activity. After 15 years the normal concrete deck is replaced. The replacement cost includes the construction cost and the costs of demolition and disposal. The residual value of the HPC deck is calculated based on the remaining service life and replacement cost.

The user costs represent the inconvenience and expenses incurred by the bridge users due to traffic disruption, which include the travel delay costs, vehicle-operating costs (VOC), and accident costs. To include these costs in the analysis, additional information is needed for each activity performed throughout the life cycle of the bridge deck.

The construction of HPC structures incorporating SCMs enables to achieve durable structures that will require fewer maintenance and repair actions over their life cycles when compared to NPC structures. This reduction in the number of maintenance and repair actions will result in a reduction in both materials and energy consumption as well as in a reduction of CO_2 emissions and waste production.

In terms of life cycle costs, the HPC deck alternative is found to be more economic in terms of both agency costs and user costs. The agency life cycle cost for the HPC deck alternative is 40%-45% lower than that of the NPC deck alternative; while the user life cycle cost of the HPC deck is 1/3 that of the HPC deck.

This example provides a good illustration of the engineering, economic and environmental benefits of using high performance concrete incorporating supplementary cementing materials for the construction and rehabilitation of bridge decks. The average life expectancy of concrete bridge is about 150 years under normal conditions.

TIMBER BRIDGES

Interest in timber bridges has grown rapidly in recent years as a result of new technologies in design and construction as well as advances in material manufacturing and preservative treatments. Despite these advances, little is known about the initial and life-cycle costs of timber bridges relative to those of other construction materials. For timber bridges, results show a relationship between cost per square meter and bridge length, load rating, and geographic location. In general, timber bridge superstructures tended to compete with steel and concrete bridge superstructures on an initial cost basis.

Most studies focus only on bridge superstructure, which includes the deck, beams, girders, wearing surface, and periphery such as guardrails. Researchers have found that substructure construction costs are more likely to vary with respect to the site as a result of differences in geological formations, soil types, and other site-specific characteristics that are difficult to quantify. A timber bridge construction includes three cost figures: (1) total superstructure cost, (2) total substructure cost, and (3) total bridge cost.

Superstructure costs included materials, labor, and transportation expenses associated with the construction of all bridge components between abutments and above bents, including stringers, beams, deck, traffic railing, and wearing surface, and costs of protective membrane and excluding approach, approach railing, detour, and mobilization. In general, timber bridge superstructures tended to compete with steel and prestressed concrete bridge superstructures on an initial cost basis. In contrast, the cost per square foot of prestressed concrete bridge superstructures is less than that of timber bridge superstructures.

Substructure costs were defined as materials, labor, and transportation expenses associated with the construction of all bridge components beneath the superstructure, including abutments and bents, and costs of excluding approach, approach railing, detour, and mobilization.

Bridge costs included all materials, labor, and transportation expenses associated with the completion of the entire bridge project, with the exception of approach, approach railing, detour, and mobilization costs.

The lifetime cost is composed of materials, labor, machinery, engineering, insurance, maintenance, refurbishment, and ultimately, demolition and associated disposal, recycling and replacement less the value of scrap and reuse of components.

There is a roughly parabolic relationship between the unit cost of timber bridge superstructures and structure length, with higher costs at both the shortest (between 6 and 15m) and longest lengths (above 45m). Additionally, there is a somewhat positive relationship between indexed unit cost and load rating. Finally, despite differences in mean unit costs among regions, there is no identifiable trend associated with this geographical breakdown.

Another component that is playing an important role in determing bridge costs is the site-specific cost determinants relating to site preparation and material and equipment transportation. The lack of standardization in timber bridge design and construction, which has resulted in ad hoc assembly practices by various transportation agencies, may also contribute to cost variability. Many transportation officials have been able to achieve low cost per square foot values using timber bridges, because they are familiar with cost-effective timber bridge designs or experienced in timber bridge construction. In addition, timber bridges may have found their market niche in the form of small-crossing, rural, and, most important, nontraditional applications that encompass a wide-range of construction practices and design concepts unique to timber. Current efforts in standardization may serve to reduce timber bridge construction costs, and increase timber bridge construction.

Timber may offer a low-cost alternative to other bridge construction materials such as steel, concrete, and prestressed concrete. Recent research indicates that timber bridges may be more durable than those constructed from other materials, particularly in cold climates where salts and other agents are frequently used. The average life expectancy of sawn timber bridges is about 40 years, and for glulam is about 100 under normal conditions. On these remarks it is hoped that the creation of a viable timber bridge market will encourage economic growth in forestry areas with underutilized timber resources.

While the cost components considered above appear relevant, there remains a largely unexplained variability in superstructure cost. This finding heightens the need for an examination of cost data for timber bridges versus those constructed of steel, concrete, and prestressed concrete. Only after a thorough comparison between material types will the large-scale feasibility of timber bridges be recognized.

CORRUGATED STEEL CULVERT

Corrugated steel culvert pipe (CSCP) is the most durable, economic, and widely chosen material for a culvert. It is cheaper, more easily transported and more easily assembled than other culvert pipes. The installation costs are reduced especially in large diameters. Being inherently durable and lightweight compared to alternative materials helps make steel the most economical option, minimising substructure costs, especially in poor ground. Because of corrugate steel's minimum self-weight culvert sections are transported to site only when needed, and easily handled once there. It provides long service life in installation that cover a wide variety of soil and water conditions.

As other pipe materials, corrosion protection is required for steel pipes. The coating provides a barrier against corrosive agents, moisture, oxygen and electrical currents. Protective, long-life coatings can easily be applied at the fabrication plant. Use of weathering steel, which needs no protective or other coatings, is increasingly popular, for aesthetic reasons as well as minimising the need for future maintenance and associated road closures.

Steel bridges lend themselves to easy and rapid strengthening or repair in the event of accidents, with well proven techniques like heat straightening ensuring that damaged structures are soon back in use.

Its life expectancy is, ideally, about 100 years under normal conditions. The design flexibility of culvert steel pipe and its predictable mechanical properties allow the engineer to design a culvert, which will withstand heavy traffic loads and whatever conditions might occur during the life of the pipeline.

CONCLUSIONS

Technical solutions choices for crossing works (bridges and culverts) is very important because it involves high capital investments for their realization and at the same time they are necessary for water streams protection and their biodiversity. The technical solution choices criteria are multiple and they refer to: location characteristics, foundation terrain, material costs, the necessary work duration, machinery and transport, but the most important criterion is represented by the overall work cost.

Costs related materials should be noted that use of local materials (wood, stone, ballast) involves lower costs than using prefabricated materials. The latter involves long distance transport, qualified staff and better heavy equipment (in case of heavy fabrications, such as concrete coffer used for flag bridges). All these elements lead to considerable cost included in labor work.

Using concrete as a basic material for abutments, wings and foundations, influence the cost of work in a largely. In case of concrete bridges, the cost for decks and abutments for small spans are frequently associated with higher abutments and more expensive foundations. Also, for spans smaller than 8 m, especially in terrains where a deep foundation is required due the inadequate bearing capacity of the superficial terrain layers, the first solution to be considered is represented by corrugated steel culverts.

Large amount of material, degree of mechanization required concrete preparation, type and trademarks used and long distance transport, generates high levels of cost. These aspects are in favor of using environmentally friendly materials that achieve harmony with the environment, because they are purchased directly from the land on which the artwork will be constructed. Thus, the transport distance is small, the acquisition cost is zero or lower than other materials. Possibility of using under-trained personnel and equipment of small size and consumption lead to cheaper labor.

If a crossing work is needed for 7-12 m spans, the most economical solution is a timber bridge (glulam). Also, the use of glued laminated timber (glulam) and corrugated steel culvert galvanized, register 20%-50% cheaper than precast concrete elements.

Acknowledgments

This research has been made in the doctoral thesis "Ecological Solutions For Art Works and Defense Consolidation" of forest roads in the region of Obcinele Bucovina, Suceava county.

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