

Life Cycle Costs for Thermal Spray Zinc Duplex Coatings on Long Lifetime Steel Constructions

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ABSTRACT

Public infrastructures like bridges typically have a design lifetime of 100 years or more. When selecting protective coatings in such a long term perspective, focus should be on life cycle costs and not only the costs in the construction phase, since the maintenance costs may be considerable and dominate the total cost of ownership. Coating selection standards like ISO 12944 are not intended for such a long timescale, and there is little documentation in the literature of coating performance with lifetimes of more than about 20 years. Owners of structures with very long lifetimes have little information to base their coating selection on, besides their own experiences. Thermal spray zinc (TSZ) duplex coatings have been shown to be highly durable, as evidenced by more than 50 years of successful use since first specified by the Norwegian Public Roads Administration (NPRA). The paper will summarize field examinations, maintenance costs, coating lifetime expectations and life cycle cost estimates for steel bridges as a function of the environmental corrosivity category (C1-C5) and make comparisons to alternative coatings that are less expensive to apply but that have shorter lifetime expectancy.

Key words: Thermal sprayed zinc, duplex coatings, corrosion

INTRODUCTION

Very often the life of a corrosion protection paint coating system will not meet the design life of the steel structure it is supposed to protect. Decisions about coating selection are usually focusing on the costs for the initial construction, ignoring the certain future maintenance costs. The total cost of ownership includes the initial cost plus the maintenance, operating and finance costs over the life of a structure. Repeated maintenance operations, and resulting downtime, can add significantly to the total cost of ownership.

For public infrastructure, the appropriateness of the maintenance strategy, and the point of intervention for renewal or rehabilitation should be planned. The process requires proactive assessment which must be based on the performance expected of the structure, the consequences and probabilities of failures occurring, and the subsequent level of maintenance needed to keep the structure sound.

International standards, such as ISO 12944-5 Protective Paint Systems,¹ outline the various paint and duplex coating systems that can be used to protect steel structures from corrosion and covers all features that are important in achieving adequate corrosion protection. Standards provide this information in the form of instructions for all stakeholders from owners, engineers, contractors, inspectors and coating system manufacturers to have current information at their disposal, in order to understand expected outcomes and to avoid problems. However, the expected performance of paint coating systems are ranked from a 'low' mark of 5 years to a 'very high' mark of only 25 years. As well, the durability of paint systems indicated by manufacturers is evaluated under circumstances guaranteeing their best performance and may not have the same real-world performance.² This can leave much uncertainty when trying to make informed decisions about coating selection for a structure with a 100-year design life.

Financial modelling can eliminate some uncertainty. Life cycle cost (LCC) calculations, such as outlined in ASTM A1068, Practice for Life-Cycle Cost Analysis of Corrosion Protection Systems on Iron and Steel Products³ provide a method for evaluating corrosion protection systems that are characterized by different maintenance requirements over the expected life of a structure. Comparing the calculated LCC of each alternate corrosion protection system determines which system provides the lowest total cost of ownership. Duplex coatings automatically have a higher initial cost than paint-only coatings. The metallic zinc coatings must first be applied, either by thermal spray zinc metallizing or by hot dip galvanizing, before the paint coating is applied. LCC analysis is well suited for determining whether the higher initial cost of a duplex coating system is justified by a reduction in future maintenance costs when compared to a paint-only alternative with lower initial costs but higher future costs.

Fortunately, some coating systems have decades of use and so there is also real-world experience which can be used to evaluate the performance of corrosion protection systems. The Norwegian Public Roads Administration (NPRA) has used thermal sprayed zinc (TSZ) duplex coatings since 1965 with good success.⁴ Including the mainland and islands, Norway has over 100,000 km of coastline, so that the steel bridges experience corrosive environments ranging from C2 to C5. The NPRA expects a coating life of 35 years before first maintenance, and then preferably only the paint topcoat shall be renewed. However, a coating performance indicator shows that many bridges are expected to reach their 100-year design life with little or no maintenance.⁵

LIFE CYCLE COST MODELING

Life cycle cost modeling provides a framework with principles, requirements and guidelines for the assessment of the economic performance of a structure, such as a bridge. Modelling can be used for the economic assessment of new bridges over their full life cycle, and also for existing bridges over their remaining service life and end of life stages.⁶

For evaluating bridge coating systems, the cost of the structure is the same and so the coating system can be isolated for modelling the life cycle costs. After initial painting, models consider three maintenance periods: Touch-up Painting, Maintenance Painting and Full Repainting.⁷ Touch-up painting is used when corrosion is limited to certain areas of the structure. Maintenance painting is more widespread and depends on the coating type, coating thickness and adhesion of the existing coating along with the condition of the steel substrate. Full repainting may be undertaken to extend the corrosion protection or only for aesthetic appearance. A generally accepted criteria for starting paint maintenance is when 5% of the steel substrate is showing visible red rust.

The modelling sequence of touch-up painting followed by maintenance painting and finally a full repainting is not always followed on actual structures. At times, multiple touch-up paintings are completed before a full repaint. Or if 5% of the surface that is showing red rust is not localized but spread over the entire surface of the structure, a full repainting may be needed from the beginning.

The life cycle costs of a three-coat alkyd painted duplex galvanized coating were compared with the same paint coating applied to bare steel on bridge structures in a C3 environment for a 55 year life. This system was modelled in order to compare with existing over 50-year-old bridges in Norway, as it approximates the four-coat alkyd paint systems used on duplex coated bridges there in the 1960's and 1970's. (A four-coat alkyd paint was not in the paint durability database used for the modelling).⁷ The model assumes a galvanized steel base, while existing bridges were zinc coated by thermal spraying. Therefore, in the model, the cost of galvanizing is taken as equal to the cost of thermal spraying used on existing bridges. The initial paint coatings are applied to both the bare steel and galvanized structures at a cost of $C = \text{NOK}390/\text{m}^2$. The touch-up painting, maintenance painting and full repainting are performed in the field at a cost, respectively of $0.5C$, $0.9C$ and $1.7C$. Touch-up painting is performed at time T . Maintenance painting (time M) is performed at time $1.5T$. Full repainting (time F) is performed at $M + (0.5T)$. For example, for a three-coat alkyd paint system $T = 12$ years, $M = 18$ years and $F = 24$ years. Then the cycle repeats. In the model, due to the synergy between the paint and the zinc coating,⁸ it was assumed for the duplex coatings that touch-up painting begins at $2T$ and that duplex coatings do not need full repainting, which involves blasting to bare steel.

The results are shown in Figure 1. The initial cost of the paint only coating is approximately 25% less than the initial cost of the duplex coating. However, with repeated maintenance painting the total cost of ownership of the paint only bridge is almost three times the cost of the duplex coated bridge after 55 years. The duplex coating is more cost effective at 12 years, after the first maintenance painting of the paint only bridge.

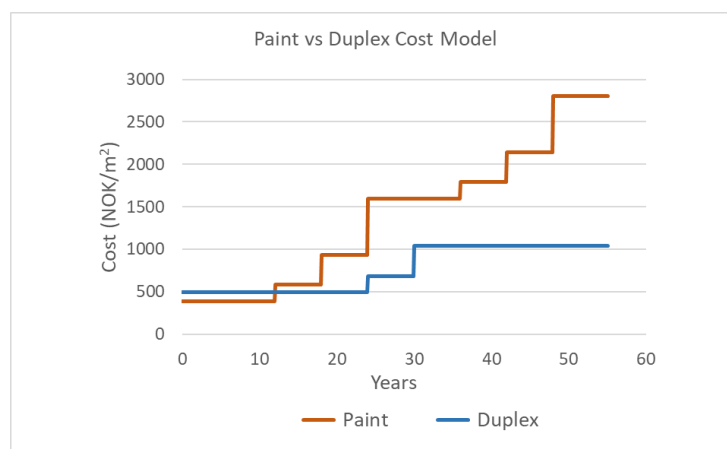


Figure 1. Life cycle cost model for paint and duplex coatings

For a direct comparison, the results of the model can be compared with two Norwegian bridges built in the early 1960's.⁴ The Brevik bridge was built in 1962, while the Rombak bridge was built in 1964. Both are suspension bridges with a strengthening truss structure, approximately 750m long, with about 40m vertical clearance for marine navigation and are both considered to be in a C3 environment. The Brevik bridge was painted, however the Rombak bridge was left uncoated until 1970 when it was field coated with a duplex thermal sprayed zinc coating. Since opening, the 58-year-old Brevik bridge paint coating has been maintained several times and the bridge was fully repainted once. In contrast, the 50-year-old duplex coating on the Rombak bridge has only received paint maintenance one time (due to topcoat flaking and not corrosion). The maintenance costs for the two bridges are compared in Figure 2. The early maintenance records for the Brevik bridge lump maintenance costs by 'decade'. Therefore, all costs in the 1970's for example are reported in the middle of the decade in 1975. Similarly, the costs incurred