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BURIED BRIDGES, MORE SUSTAINABLE, MORE DURABLE

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Abstract:

By offering better alternatives to traditional bridges, Buried Bridges now deliver maximum value and road safety. Continuous research, product improvements and more durable coatings have elevated the performance characteristics of buried bridges to the point where they are now legitimate contenders in markets, environments and sites from which they were previously excluded. From projects across Canada, the resilience of buried bridges has demonstrated their ability to withstand extreme weather events, over time. After surviving severe flooding, and even hurricane events, buried bridges were often the one bridge left standing. By minimizing the natural and financial resources required, Buried Bridges yield a positive environmental impact. Mitigated durability, hydraulic flows, traffic disruptions and climate change risks are among their accrued benefits; moreover, high recycled content and reduced construction waste make buried steel bridges ideal for Environmental Product Declarations. And maximizing value to owners contributes to benefits for the entire population.

1 CORRUGATED STEEL PIPE INSTITUTE

The Corrugated Steel Pipe Institute (CSPI) is the association that represents Canadian corrugated steel pipe (CSP) manufacturers. We are an impartial organization that works with our member manufacturers, along with municipalities and engineers around the world, to gather and compile relevant information, news, innovations and performance data. In Canada, we serve as the country's essential information resource regarding water & soil management practices. Armed with more than a hundred years of engineering knowledge, data and technical expertise, we provide ongoing assistance to the public, government officials, and construction engineers seeking the most prudent solutions for their projects, in order to maximize their return on every dollar spent.

2 BURIED BRIDGE DEFINITION

Buried bridges are:

- bridges with spans greater than 3 meters, that offer resistance to protect structures from the potential ravages of hostile elements within the surrounding soil
- distinct from bridges, in that buried bridges require methods of design analyses that consider and address potential soil-interactions with CSP
- distinguished from culverts, in that they generally pertain to larger structures that are of critical importance for highway safety

Structural plate corrugated steel (SPCS) has been manufactured and used in Canada since 1934. For decades, Canada has been responsible for the development and introduction of many technical performance innovations to structural plate products, and has exported these improved technologies to customers and organizations domestically and around the world.

Figure 1: This SPCS installation, at Cape Spear, Newfoundland, is an underground bunker, constructed in 1941, to store the 600 lb shells used with anti-submarine artillery. It is one of the oldest and the most easterly SPCS installations in North America, and travellers can still visit the site today.

3 PROFILES & SHAPES

In the early days of production, the conventional corrugation profile of SPCS was 152mm pitch (crest to crest), by 51mm depth (crest to valley). These early structures required circumferential stiffening members (ribs), horizontal sizing cables and struts, or supports, for long span structures. These developments made it possible to achieve clear spans up to 18 meters, and clear areas up to 100m^2.

In the 1990s, extensive research and development resulted in the creation of much larger corrugation profiles, which featured both increased pitch and depth. These profile innovations enabled the development of new SPCS products offering much larger profiles than previously available, including 400mm x 150mm and, the latest variant, at 500mm x 237mm.

These new, deeper corrugated profiles eliminated the need for the additional strengthening and stiffening requirements of earlier SPCS structures. The increased stiffness and load resistance of these larger profiles have significantly increased the practical application limits of SPCS structures, which can now accommodate spans of up to 30 meters, or more. Although they are technically still considered to be 'flexible' structures, during installation these deep corrugation profiles effectively produce rigid structures.

Detailed design procedures covering installation of these long span structures can be found in the Canadian Highway Bridge Design Code (CHBDC), as well as in the latest edition of the AASHTO (American Association of State Highway and Transportation Officials) Standard Specifications for Highway Bridges, Section 12.7, and LFRD Bridge Design Specifications, Section 12.8. These standards provide for the selection of acceptable combinations of plate thickness, minimum cover requirements, plate radius and other design factors.

Figure 2

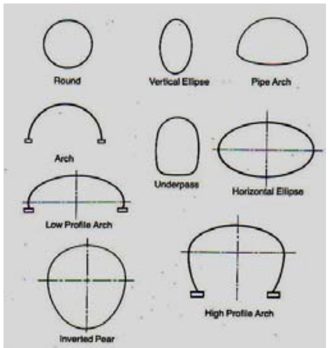
152mmx 51mm | 400mm x 150mm | 500mm x 237mm

1.5 – 8M | 8 – 24M | 8 – 30M +

Span

Designers can choose from a wide range of standard cross-sectional shapes of corrugated steel and structural plate conduits, as shown in Figure 3. Prudent designers must determine the optimum shape based on several criteria, including the size of the structure and its service use, but must also consider other factors, such as the strength and economy of the design. (CSPI Handbook 2009).

Figure 3



4 BENEFITS OF BURIED STRUCTURES

The myriad applications in which buried CSP structures serve include: bridges; highway and railroad overpasses; stream enclosures; tunnels; culverts; and conveyor conduits. Because these structures offer so many advantageous benefits over other materials, they are extremely popular for bridge replacement projects. When used in this manner, buried CSP bridges:

1. eliminate icing problems on bridge decks
2. prevent bridge deck deterioration
3. end the need for constant maintenance of bridge approaches and painting of the superstructure.
4. permit the use of a constant roadway section in the vicinity of the structure.
5. enable the roadway to be easily widened, simply by extending the ends
6. are readily available and can be field assembled with unskilled labour
7. reduce the time required for design and construction, thereby facilitating faster project completion
8. are environmentally superior, in that they reduce carbon footprints, while retaining the natural appearance of a site’s earth slope and vegetation
9. are more economical and lightweight, which reduces transportation costs
10. offer a 75+ years material service life for specific environments

In 2013, there was a major flood event – an alluvial fan – in Canmore, Alberta. Extremely heavy rains, combined with a mountain snow melt, quickly and violently transformed the neighbourhood creeks of this picturesque little town into raging torrents. Estimated damage to the homes along Cougar Creek alone was more than $6 million CDN. However, one bridge did survive – a corrugated structural plate buried steel bridge. Why did it withstand the ferocious flooding when others were quickly washed out? Because it was designed with careful attention to proper headwall treatment and was, therefore, kept clear of debris, allowing water to run through freely. (Geddes 2014)

Figure 4

Residents watch the flooding Cougar Creek as it takes out Eagle Terrace Road (C) and nears the top of the Elk Run Blvd Bridge June 20, 2013 in Canmore, Alberta.

CANMORE, CANADA- JUNE 21: A woman walks along the edge of Eagle Terrace Road which collapsed into the river, looks at the destruction along the Cougar Creek June 21, 2013.

5 DURABILITY OF COATINGS

As per CSA G401-14, there are two plate coatings available: Hot Dip Galvanized and Polymer Coated. Galvanized coatings date back to 1930 and are well known within the bridge industry. Polymer Coated CSP was developed in 2005 to improve durability of the product when installed in environments with specific, corrosive and abrasive chemistry. There are three primary environmental conditions to consider when determining what materials will be most durable for a buried structure application: soil, water, and anthropogenic impacts. The thermoplastic polymer system is comprised of the steel substrate, a zinc rich primer, containing a minimum of 60 wt% zinc, and an ethylene acrylic acid (EAA) copolymer topcoat, containing a minimum of 85 wt% EAA. (CSA G401 2014)

Laboratory testing concluded that, in every aspect of performance, polymer coatings far exceeded the protection offered by galvanized. Two of these tests were of primary interest: corrosion resistance, as measured by exposure to salt spray; and abrasion resistance, by sandblasting the product in cycles. In salt spray exposure tests over time, polymer coatings outperformed the metallic coatings by 5,000 hrs. When subjected to abrasion testing, after completing full four cycles, 84% of the original galvanized thickness was gone, but only 0.5% of the thermoplastic polymer coating's thickness was depleted. As a result of the testing, thermoplastic polymer coated structural plate is expected to provide significantly improved longevity for buried steel structures, in a far broader range of environments than was previously possible. Through analysis of all test data and an extensive literature review by a qualified Corrosion Engineer, a predictive model was developed to forecast the long-term field performance of the coated SPCS material. These models and analyses are captured in the Performance Guideline for Buried Steel Structures and its supporting White Paper (at www.cspi.ca). Since its first installation beneath a section of Highway 401, near Kingston, Ontario in 2005, thermoplastic polymer coated plate has grown in popularity and is now spread across Canada. In fact, there are now more than 200 installations in Canada, as verified by Warner Custom Coatings. (Williams and Carrol and West 2012, Villeneuve and Penny 2012)

Table 1 (CSPI 2012)

Table 2

Environmental Limits For Galvanized Steel and Polymer Coated Steel

Environmental Parameter	Suggested Limits Galvanized Steel	Suggested Limits for Polymer Coated Steel		
		50 Year EMSL	75 Year EMSL	100 Year EMSL
pH Preferred Range	5 - 9	3 to 12	4 to 9	5 to 9
Resistivity	2,000 - 8,000 ohm -cm	> 250 ohm cm	> 750 ohm cm	>1,500 ohm cm
Chlorides	< 250 ppm	NA[1]	NA[1]	NA[1]
Sulfates	< 600 ppm	NA[1]	NA[1]	NA[1]
Hardness	> 80 ppm $CaCO_3$	NA[1]	NA[1]	NA[1]

Note:
[1] Resistivity is relative to total dissolved solids (TDS) and therefore may indicate the presence of chlorides, sulfates, calcium and other ions.

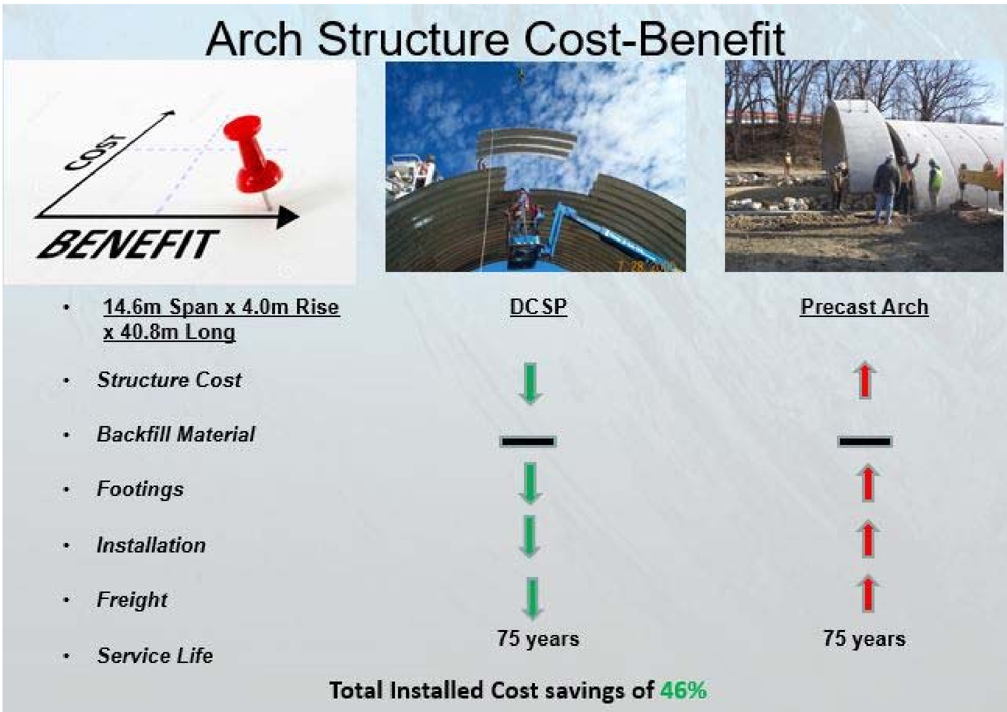
6 DELIVER MAXIMUM VALUE TO OWNERS

Choosing the type of bridge to select or design involves a number of factors, including: material service life; safety, aesthetics; innovation; access and mobility; maintenance of biodiversity; hydraulics; impact on climate; and of course, the economic impact of the material chosen. Using buried bridges versus traditional bridges reduces installed cost by 33 to 67% (Transportation Research Board – 2012). Spinoff benefits resulting from those cost reductions include:

- Reduced construction time (ease of installation – no large cranes needed)
- Increased bid competition
- Reduced environmental footprint
- Reduced maintenance
- Low life cycle cost - 75 to 100 years
- Economical shipping to remote locations – nested on one truck

Figure 5 depicts a recent project in Ontario, comparing a cost benefit comparison of materials:

Figure 5 (CSPI / member Armtec 2016)



7 PROJECTS ACROSS CANADA

As a result of ongoing product and material improvements, in tandem with ongoing educational initiatives among transportation departments and engineering consultants, the popularity and preference for constructing corrugated steel buried bridges continues to grow across Canada. In fact, installations can be found in every province, in both rural and urban centers. Recently, the city of Calgary opted to construct buried SPCS bridges in three of its key urban areas, in order to divert money saved towards their infrastructure budget, as depicted in Figures 6.

Figure 6

Mahogany in SE | Elbow Valley SW off Hwy 8 | Quarry Park

8 SUSTAINABILITY

Most developed countries enjoy a high quality of life; however, they currently do so by consuming materials and finite natural resources at a rate our planet cannot continue to support. This cavalier approach devours precious resources with little restraint, overburdens ecosystems with excess waste and pollution, while neglecting the oversight, care and upgrading of our supporting infrastructures. When aggregated, these failings actually disrupt the social fabric of our societies, thereby undermining the ability of future generations to sustain the quality of life we currently enjoy. (TAC 2014)

Steel is, in fact, 100% recyclable. Moreover, the steel from which CSP products are manufactured comprises more than 50% recycled steel; importantly, recycled steel suffers no degradation whatsoever, retaining 100% of the properties of virgin steel. Additionally, our products are much lighter that our competitors' and can be nested on trailers, which significantly decreases the energy required for transportation to project sites.

Additionally, within the corrugated steel products sector, R&D drives continuous product and process improvements; accordingly, new alloys and application-specific, protective coatings have kept pace with advancing technology to render today's corrugated steel a leading, state-of-the-art, eco-friendly building material with longer service life.

For the past 25 years, Canada's steel manufacturing industry has continuously lowered its carbon footprint, through enhanced practices in the manufacturing and recycling of steel products, thereby effecting reductions in: greenhouse gas emissions; ozone depletion and smog air, while increasing the use of renewable energy sources, enhanced waste disposal procedures and more efficient end-of-life recycling. (Coon 2017)

Figure 7

9 ENVIRONMENTAL PRODUCT DECLARATION

Results from a major research project, undertaken on behalf of steel manufacturers to ascertain the environmental impact of steel were recently released. We worked with a third-party company that studied the data from this research, extracted and compiled results that relate specifically to corrugated steel products to create an Environmental Product Declaration focused expressly on the environmental performance of corrugated steel products.

Specifically, the association declaration provides an assessment of the environmental impact of corrugated steel products on: climate; resources; greenhouse gas emissions; acidification; energy consumed in mining, manufacturing and recycling; attainable LEEDs points, etc. Steel is a remarkable material that, when used wisely by qualified designers, can significantly reduce consumption of the world's limited resources.

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