Orthotropic Design

Closed Orthotropic-Rib Bridge Construction

Orthotropic Bridge Design

Orthotropic is a term used to describe an ***ortho***gonal-aniso***tropic*** structure. This type of structure exhibits different mechanical properties along different perpendicular axes. When used to describe a bridge structure, orthotropic simply means that the bridge's mechanical properties along the direction of travel are different from those across the width.

There are several types of orthotropic designs. The one used by METTLER TOLEDO consists of a deck reinforced by closed ribs with a trapezoidal shape. A proven design that is widely used in bridge construction, it was chosen to replace the driving surface of the Golden Gate Bridge. It was also used to rebuild the infrastructure in postwar Germany. So why don't more people use it? The answer is simple: $$$. It requires a large up-front investment to produce this type of structure. Not everyone is committed to providing this level of quality.

Open Rib versus Closed Rib

There are many ways to design an orthotropic bridge section. The two most common are the open-rib deck (Figure 1) and the closed-rib deck (Figure 2). Please note that the closed-rib design is constructed of individual ribs, not a sandwich of plates and beams. The sandwich design does not offer the same structural efficiency as the closed-rib design. Although the open-rib and closed-rib concepts are similar, the closed-rib design is significantly stronger. Let's take a look at why.

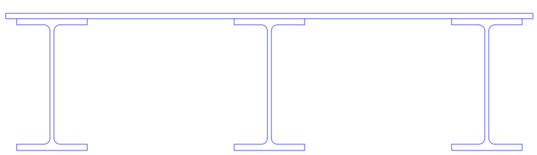

Figure 1: Open-Rib Orthotropic Design, No Load

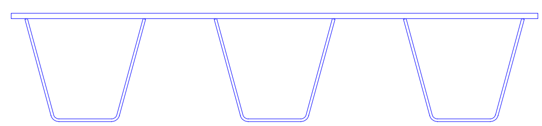

Figure 2: Closed-Rib Orthotropic Design, No Load

A truck's weight is concentrated at the load points where its tires meet the surface of the bridge. To reduce the stress at those load points, the bridge design should spread as much of the load as possible to the ribs adjacent to each load point. Because the closed-rib design is better at distributing the load across several ribs, it is stronger and more efficient.

Notice how each design reacts when a load is concentrated directly over one of the ribs (the deflections are exaggerated to show the effect more clearly). In the open-rib design (Figure 3), the I-beams adjacent to the load point are bent. Because the load is not transferred through these adjacent beams in a straight line, they support less of the load. In the closed-rib design (Figure 4), the torsional rigidity of the ribs resists the tendency of the load to deform them. As a result, the adjacent ribs provide significant support and the load is distributed more evenly across the ribs.

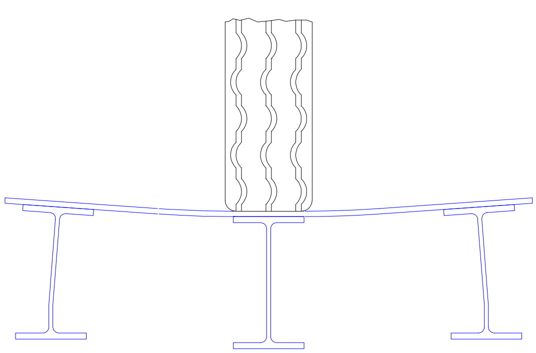

Figure 3: Open-Rib Orthotropic Design, Loaded

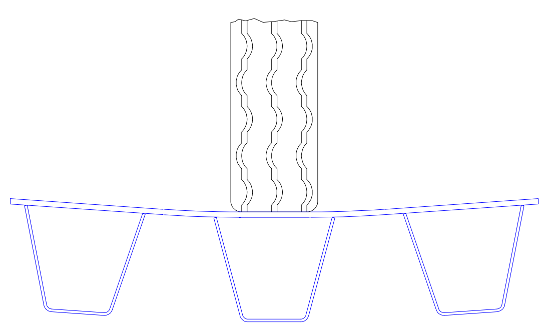

Figure 4: Closed-Rib Orthotropic Design, Loaded

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Another benefit of the closed-rib design is that the ribs resist buckling. Figure 5 shows an open rib that is directly under the load. The beam's web can buckle to either the right or left, causing the rib to fail. To protect against buckling, you would need to add stiffeners to the beam. Figure 6 shows one leg of a closed rib and the direction in which it will always tend to buckle. Figure 7 shows a closed rib with a trapezoidal design. Since each leg tends to buckle toward the inside of the rib, the two forces act against each other. The flat section connecting the two legs transfers the load from one leg to the other, eliminating the possibility that the rib's legs will buckle. What if the closed rib were square (Figure 8) instead of trapezoidal? As with the I-beam design, the legs can buckle in either direction. The flat bottom of the rib is less effective because both legs could fail in the same direction, causing the rib to collapse.

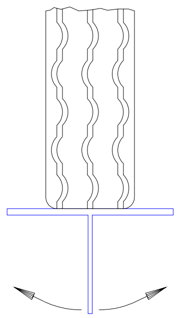

Figure 5

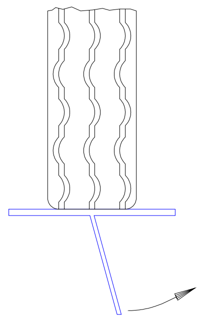

Figure 6

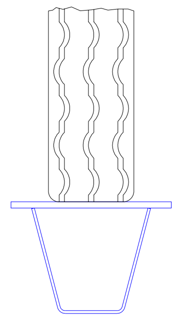

Figure 7

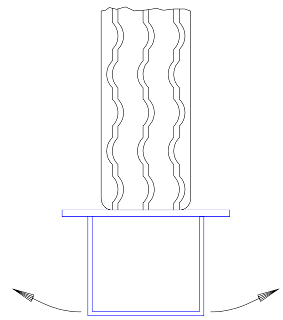

Figure 8

It is difficult to analyze the actual strength of an orthotropic bridge structure. The calculated strength is usually a small factor of the actual strength. Tests have shown that the actual strength of the open-rib design is 10.3 times greater than the computed strength. Similar testing on the closed-rib design could not be completed because the test equipment failed at 42 times the computed strength (*Design Manual for Orthotropic Steel Plate Deck Bridges*, American Institute of Steel Construction, 1963, pp.19-20).

METTLER TOLEDO Closed Orthotropic Rib

The METTLER TOLEDO closed-rib orthotropic steel deck design offers several other advantages. The three main ones are aimed at extending the life of the scale by reducing metal fatigue and internal corrosion.

1. The closed-rib design resists metal fatigue because there are no welds in the areas of the bridge that experience the greatest stress. The welds are located as close as possible to the neutral axis. What is the neutral axis? When a vehicle is driven onto a scale module, the module bends. Its top surface is pushed together (placed in compression), and its bottom surface is pulled apart (placed in tension). As you move downward from the top surface, the amount of compression decreases. As you move upward from the bottom surface, the amount of tension decreases. At some point near the center of the structure, the stress point is zero (it is in neither compression nor tension). This point is called the neutral axis. The actual position of the neutral axis will vary, depending on the geometry of the module. In the closed-rib design, the neutral axis is closer to the top surface of the deck (Figures 9 and 10). The greatest stress is at the surface that is farthest from the neutral axis, in this case the bottom of the rib. The welds are located in the lower stress region where the ribs meet the underside of the deck plate, near the neutral axis and far from the bottom of the rib.

2. The design also reduces metal fatigue by using continuous welds to join the rib to the deck plate. A start or stop in a weld increases local stresses and the potential for failure. For this reason, we do not use intermittent welds.

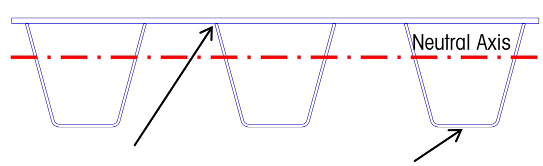

Figure 9: Scale Cross Section

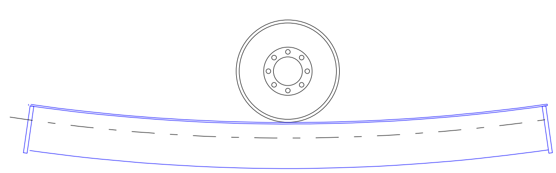

Figure 10: Scale Side View

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3. The closed-rib design helps extend the life of the scale by reducing the possibility of internal corrosion. Each rib is completely sealed to limit the amount of moisture inside the rib chamber. Once the small amount of moisture sealed inside the rib has reacted with the metal to form iron oxide (rust), the rusting process stops. Since no more moisture can penetrate the chamber, there is no possibility of the scale rusting from the inside out.

METTLER TOLEDO has invested the time and money to develop and manufacture the industry's premier vehicle scale weighbridge. If you have questions about our weighbridges or about any of the information in this data sheet, please do not hesitate to contact us for clarification.

Contact your local METTLER TOLEDO authorized distributor or sales office for more information.