

Behavioural Study of Truss Bridge using Isogrid Members

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Abstract

The search for lightweight and highly efficient structural components is a continuing process. Reducing the structural weight and improving the load carrying capabilities of these structures will allow designers to append additional capabilities while reducing cost. Isogrid is a lattice of stiffened ribs forming an array of contiguous equilateral triangles. This rib pattern forms triangular trusses by maintaining isotropic property. Ribs when arranged in 60° pattern are known as Isogrid. The highly redundant nature of Isogrid stiffening concept provides high efficiency distributing loads and is less susceptible to impact damage, delamination, and crack propagation. Isogrid structure is typically found in stiffness critical components that resist buckling. The behavior and performance of Isogrid deck slab in a Bridge supported by the truss girders is studied. Isogrid is modeled, analyzed and designed using commercial Finite Element (FE) software. In the present work, a truss bridge is designed for a span of 10.305 m. The bridge is designed using three different kinds of deck configuration, rectangular section without skin, inverted T section with skin, and I section with skin. Commercial FE software is used for computing deflections and stresses. It is found that the deck profile of I section with skin is more preferable than other configurations for Truss Bridge.

Keyword: Isogrid, Bridge, Deflection, Stresses

1 Introduction

For every engineer a bridge construction is a great challenge caused by the high complexity compared to other areas of structural engineering. Especially since the needed span lengths, bridge widths, loads and other requirements are changing with time. By those new challenges bridges are changing in new systems, new designs, new manufacturing methods and new materials.

It is often necessary to cross a river or any other obstacle where no bridges exist or they have been collapsed. In general already prefabricated bridge elements will be used. They are mostly made out of light, well transportable and screwable parts from high quality materials which could be fast built to bridges with different span, width and load capacity. In the composites industry, lattice/ mesh/ grid structure composites are structural materials with promise to realize the long-sought goals of being both lightweight and high strength. Isogrid has also a long history; McDonnell Douglas presented many formulas for the composite Isogrid in 1973. The report "Isogrid Design Handbook" [2] has given analytical techniques for a wide range of Isogrid applications. The research article [3] deals with the grid structure strengths, grid structure weaknesses, the effects of empty, soft, hard and rigid inclusions, the effects of missing ribs, the effects of nodal offset, the impact of soft and hard repairs to the grid structure lattice, and the impact of joining grid

structures together which would be fundamental concept to understand and to analyze the grid structure characteristics and failure concepts. Stress and Deflection Analysis of Orthogrid and Isogrid Structure [6] describes that Orthogrid and Isogrid concepts will be used for skin stiffening applications.

In the present work, a truss bridge is designed for a span of 10.305 m. The bridge is designed using three different kinds of deck configurations, rectangular section without skin, inverted T section with skin, and I section with skin. Commercial FE software is used for computing deflections and stresses. It is found that the deck profile of I section with skin is more preferable than other configurations for Truss Bridge.

1.1 About Isogrid

Grid structures are characterized by a lattice of rigid, interconnected ribs. This configuration proves to be an inherently strong and resilient arrangement for composite materials, without the material mismatch associated with laminated structures. The absence of material mismatch implies that grid structures possess inherent resistance to impact damage, delamination and crack propagation. In addition to showing a high potential for automation, the fabrication process for grid structures may be simplified greatly over that for composite laminates as it may not .

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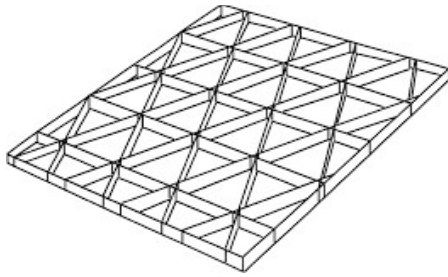


Figure 1- Geometry of Isogrid

require bagging, debulking or use of an autoclave, reducing costs considerably. Grid structures have been in use for decades. Most of them were manufactured using metals and concrete. Composite grids offer high resistance to loads and provide high stiffness to low mass. Grids are different from sandwich constructions. Commonly available manufacturing processes such as filament winding, pultrusion and tubes made from female mold can then be made in large sizes and quantities “Isogrid” has everything in its name, as these structures act like isotropic materials. Isogrid is a lattice of stiffening ribs forming an array of contiguous equilateral triangles. This is the simplest arrangement of bar elements that exhibits isotropic properties, hence the name Isogrid.

Intersecting ribs so arranged make a complete structure whether attached to a skin as stiffening or used as an open lattice. When a load is applied to this kind of structure it will be equally distributed among the stiffeners. Geometry of its structure is shown below in Figure 1.

The Isogrid lattice is a complete structure by itself, that is, it can effectively resist tension, compression, shear, and bending loads. Stiffened by such a lattice, a skin has the same capabilities. Therefore, either skin or lattice can be locally reinforced to handle local loads or discontinuities from cutouts.

Objective of the present study

1. Modeling and analysis of Isogrid panel using commercial FE software.
2. Analysis and design of truss girder system bridge using Isogrid panel.
3. Modeling of Isogrid panel with different profile such as rectangular section, inverted T section and I section.
4. Analysis and design of 10.3057 m truss Bridge with different Isogrid panel profile, and comparison of these profiles performance and computing the deflections and stresses for the Bridge.

2 Analytical Study

The Bridge with an Isogrid panel is modeled in commercial FE software. In this models dead, live & wind loads are applied and the Bridge is simply supported. All elements of the bridge rather than deck are modeled as beam elements in the model. According to different profiles of Isogrid panel in deck, 3 models are prepared for 10.3057 m span of the Bridge.

2.1 About Material

a. Material properties for Isogrid panel:

- Material-Carbon Reinforced Fiber(CRF)
- Density-1500 kg/m³
- Young's modulus-120 GPa
- Poisson's Ratio-0.3

b. Material properties for Truss:

- Material-Aluminium
- Density-2700 kg/m³
- Young's modulus-70 GPa
- Poisson's Ratio-0.27

2.2 About Loading

Bridge is designed considering following load cases

- Live Load - 4.0 KN/m²
- Wind load - 551.7 N/m²

2.3 Analytical Model

The Bridge is modeled to cross obstacle up to 10.3057 m. In Figure 2, x is a direction along length of bridge; y is the vertical direction while z is the direction along wind (transverse).

2.4 Different profiles of Isogrid panel

1. Rectangular section of Isogrid panel without skin

Rectangular section is applied to the wire elements and for truss member box section is provided. Isogrid panel is made up of wire elements.

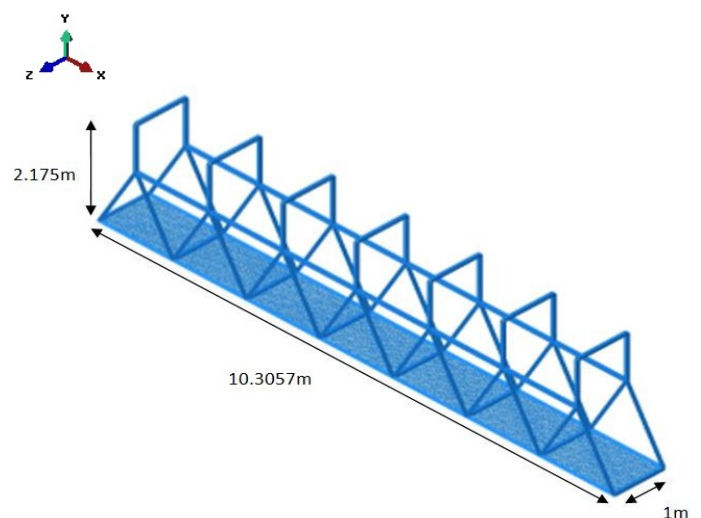


Figure 2- Bridge of span 10.3057 m

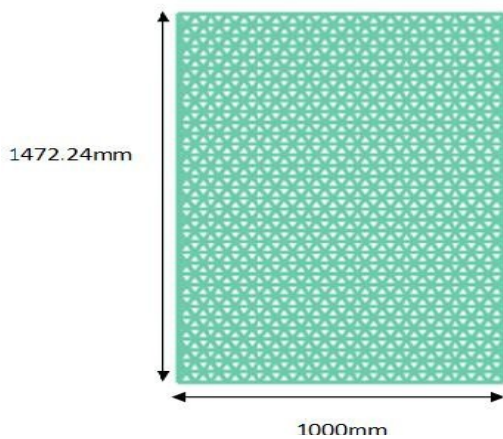


Figure 3- Profile of Isogrid Panel without Skin

For Truss member – Box section size (60 mm x 60 mm x 5 mm)

For Isogrid member – Rectangular section size (7 mm x 14 mm)

2. Inverted T Shaped Isogrid Panel with Skin

Inverted T shaped Isogrid panel with skin is used in deck slab. Isogrid panel is modeled with shell elements and truss members are modeled with box section.

In inverted T shaped Isogrid panel with skin dimensions of flange (4 mm x 1.5 mm), web (2 mm x 5 mm), and thickness of skin is 1 mm.

For Truss member – Box section size (60 mm x 60 mm x 5 mm)

3. I Shaped Isogrid Panel with Skin

I shaped Isogrid panel with skin is used in the deck slab. I shaped Isogrid is modeled with shell elements and truss members are modeled with Box section.

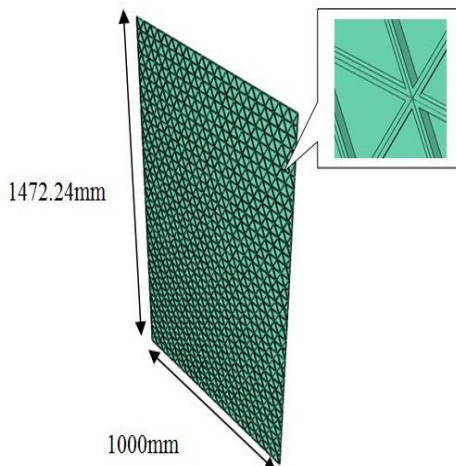


Figure 4- Inverted T Shaped Isogrid Panel with Skin

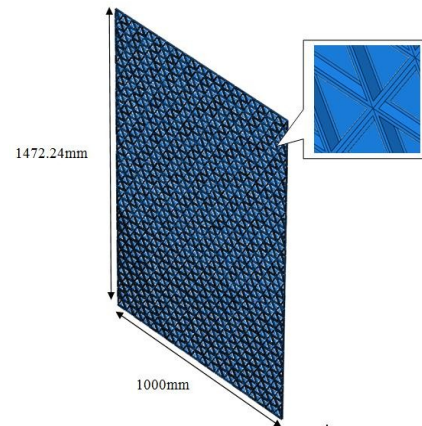


Figure 5- I Shaped Isogrid Panel with Skin

In I shaped Isogrid panel with skin dimensions of flange (4 mm x 1 mm), web (2 mm x 5 mm), and thickness of skin is 1 mm.

For Truss member – Box section size (60 mm x 60 mm x 5 mm)

3 Results

Analysis of the Bridge is done using commercial FE software and results are extracted in the form of deflection and maximum stresses. Following two different load cases are studied for all three profiles of Isogrid panel.

- Live Load+ Dead Load of bridge
- Live Load +Dead Load of bridge +Wind Load

3.1 Live Load +Dead Load of bridge

From results for load combination-1 it is seen that Y – Deflection for I section is 38.98% less than T section and 8.88% more than rectangular section and maximum stress for I section is 0.74% less than T section and 16.52% more than the rectangular section.

a. Deflection

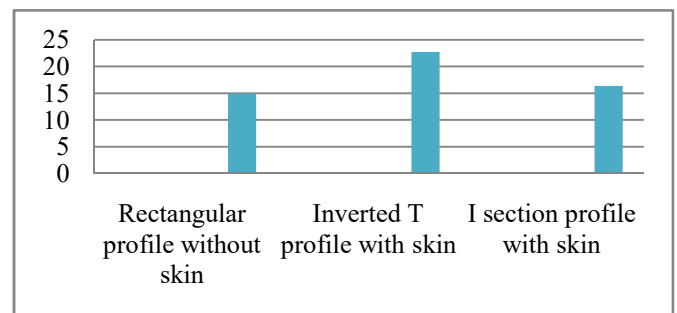


Figure 6-Deflection in Y direction

b. Maximum Stress

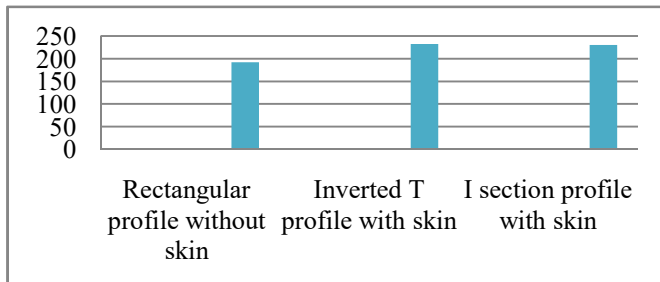


Figure 7- Maximum Stress

3.2 Live Load +Dead Load of bridge +Wind Load

a. Deflection

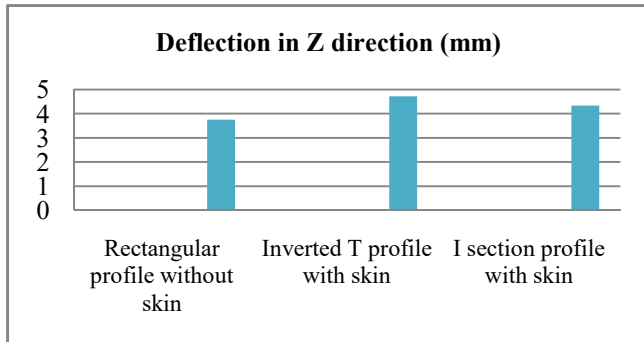


Figure 8 - Deflection in Z direction

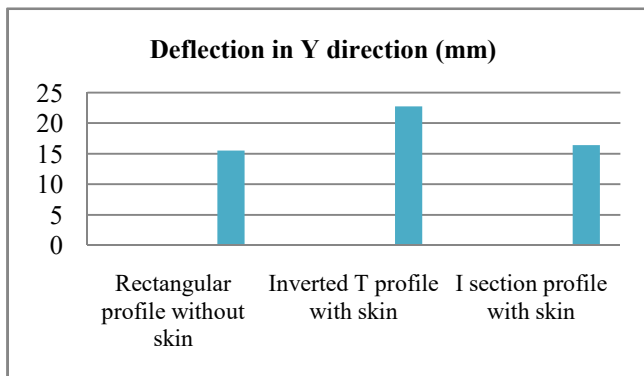


Figure 9 - Deflection in Y direction

b. Maximum Stress

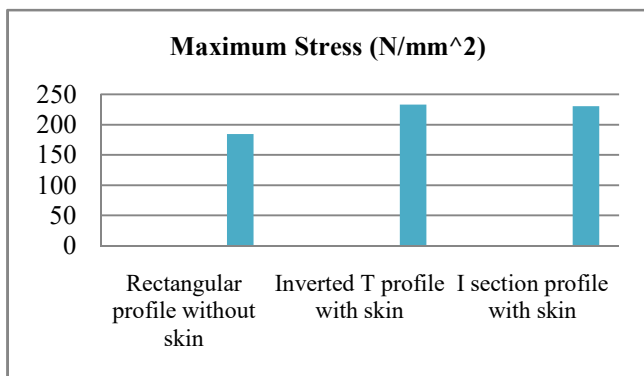


Figure 10 - Maximum Stress

From results for load combination-2 it is seen that Y – Deflection for I section is 38.86% less than T section and 5.36% more than rectangular section and for Z-Deflection for I section is 8.89% less than T section and 13.57% more than rectangular section. Maximum stress for I section is 1.08% less than T section and 20.06% more than the rectangular section.

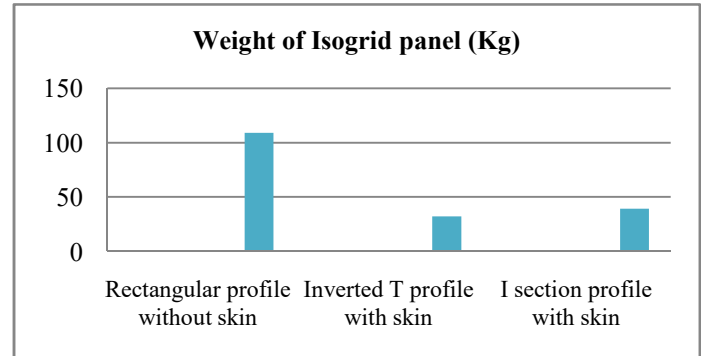


Figure 11 - Weight of different profile of Isogrid panel

3.3 Weight comparison of different profiles of Isogrid panel used in Bridge

From results for load combination 1 and 2 it is seen that for bridge formed by Rectangular section profile without skin of Isogrid panel has minimum deflection in both Y and Z direction and also stress in all load combination, but its weight is greater than inverted T with skin Isogrid panel and I section with skin Isogrid panel.

Skin is provided to the deck in Inverted T and I section profile, the properties of the skin distributes the load uniformly.

I section profile has minimum deflection in Y direction (flexure), in Z direction (wind) and also developed stress is less than Inverted T section profile.

4 Conclusion

It can be concluded that composite material, i.e. CRF, can be used as main material for Bridge deck construction. Thus, reducing the weight of the structure significantly, compared to aluminum alloy.

From the above results it can be observed that bridge deck of I- section with skin is more efficient than rectangular and T-section.

Disclosures

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