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Loading Resistance of Corrugated Web Girders

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***Abstract*: The corrugated steel plate has been used in the field of structural applications for a long time because of its many advantageous properties. Steel and concrete composite bridges have been considered as an attractive solution for short and medium span bridges due to the benefits of combining both the two construction materials. In this paper girder is composed of steel and corrugations are introduced in the web region. Different shapes of corrugations were introduced in the web region and studied analytically using the software ANSYS 16.1. Shape study was conducted based on two assumptions, profile wave as constant and profile weight as constant. Study based on profile weight constant is highly accepting and Trapezoidal shape is best for web corrugation.**

***Keywords*: Corrugated steel plate, profile wave constant, profile weight constant.**

1. Introduction

Replacement of the concrete webs in a concrete box girder bridge with corrugated steel webs considerably reduced the self-weight of the bridge by 10–30% and improves the seismic performance of the bridge. The corrugated steel plate has been used in the field of structural applications for a long time because of its many advantageous properties. Steel and concrete composite bridges have been considered as an attractive solution for short and medium span bridges due to the benefits of combining both the two construction materials. The continuous composite girders are the most common forms of bridge structures. The composite bridges with corrugated steel webs have many properties, such as lightness in weight, construction period is very low, aesthetically appealing, good seismic performance and optimum force distribution.

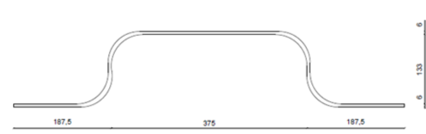
Advantages of replacing the conventional webs of box girders with corrugated steel webs are listed as follows: (1) the dead weight of corrugated steel webs are very low as compared to concrete webs, leads to reduction in seismic forces and smaller substructures, which will result in lower construction cost and the ability to increase the girders length; (2) the corrugated steel webs without additional stiffeners have higher shear buckling strength as compared to that of flat plate steel webs; (3) the corrugated steel webs can be fabricated and constructed more easily than concrete webs; (4) Shear forces can be distributed optimally into corrugated steel webs and bending forces to concrete slabs. As we know economical design of girder results in thin webs. But if the web is thin, problem of plate buckling may arise. It can be solved by using thicker webs or stiffeners. The best way to solve the problem of web buckling is the introduction of corrugations in the web. The purpose of using corrugated web is that it allows the use of thin plate without any additional stiffeners and also reduces the cost of fabrication and improves fatigue life. In this study different shapes of web corrugations were studied analytically using the software ANSYS 16.1.

2. Methodology

Replacement of the concrete webs in a concrete box girder bridge with corrugated steel webs considerably reduced the self-weight of the bridge by 10–30% and improves the seismic performance of the bridge. Cognac bridge was the first prestressed composite box girder bridge with corrugated steel webs built in France in 1986. In this paper different shapes of corrugation profile were studied using ANSYS 16.1. Trapezoidal, rectangular, square and triangular shapes were used. In this paper shape study was conducted based on two different assumptions. (i) profile wave as constant and (ii) profile weight as constant.

3. Geometrical details

The aim of the test is to determine the loading resistance by different geometrical arrangements for the web corrugations. The web of all the girders were 500 x 6 mm, the flange width is 225 mm and the thickness of flange varies between 20 and 30 mm. Span is 1875 mm.



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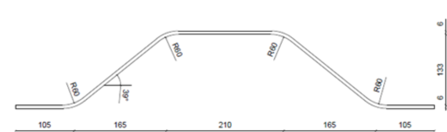

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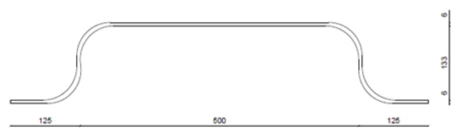

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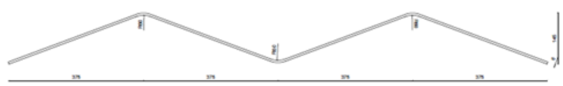

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Fig. 1. Geometry of Different Shapes (i) Rectangle, (ii) Trapezium, (iii) Square, (iv) Triangle

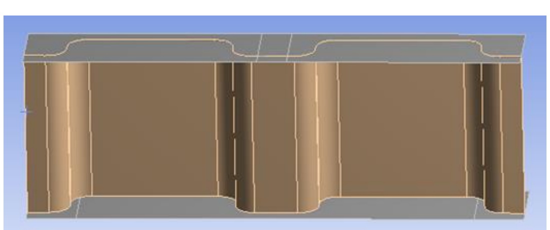
4. Material Properties

Table 1
Properties of Girder

Flange	Web
Grade – Fe 345	Grade – Fe 345
Poisson's Ratio – 0.3	Poisson's Ratio – 0.3
Yield strength – 373 MPa	Yield strength – 379 MPa
Density – 7860 kg/m³	Density – 7860 kg/m³
Young's modulus – 20000 MPa	Young's modulus – 20000 MPa
Bi linear property	Bi linear property

5. Finite Element Analysis

The ANSYS 16.1 software was used to model all the specimens for nonlinear analysis. SOLID 186 from ANSYS library was used for 3-D finite element modeling of the corrugated web girders. Four different shapes of corrugations were studied using ANSYS 16.1. (rectangle, trapezium, square and triangle). Firstly, the number of waves of corrugations of all the four specimens were kept as constant. So that all the specimens are having different weight. Fixed support was given for all the specimens. Uniformly distributed load was applied. Secondly, finite element modeling was done by keeping the weight as constant. FE models of corrugated web girders with different shapes are shown in fig. 2.



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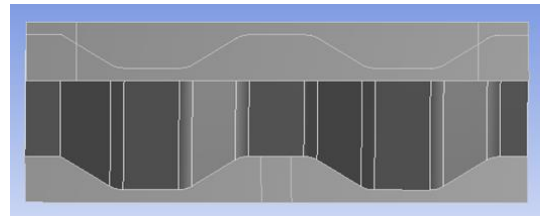

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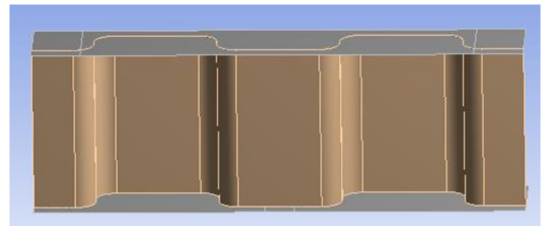

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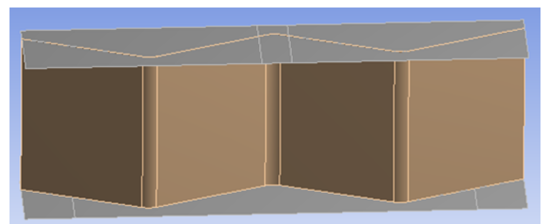

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Fig. 2. Finite Element Models of Different Shapes (i) Rectangle, (ii) Trapezium, (iii) Square, (iv)

6. Results

A. Load deformation

The profile wave as constant shows that, rectangle as the best shape for corrugation. But in actual practice, it is not possible. Because the rectangular corrugations have the highest weight as compared to others. As we know, as the strength increases, load carrying capacity also increases. From the profile weight constant (the weight of all the four corrugated shapes are kept as constant), the best shape of corrugation is trapezoidal. Load deflection graph of profile wave constant and profile weight constant are shown in fig. 3 and fig. 4 respectively.

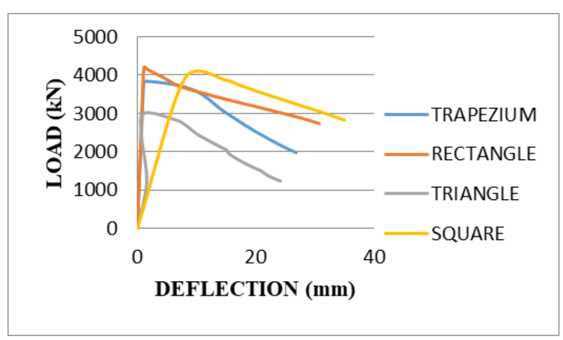


Fig. 3. Load Deflection Graph of Profile Wave Constant

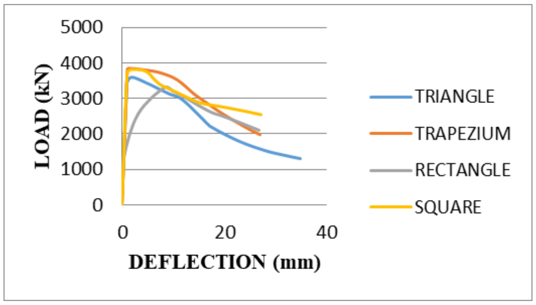
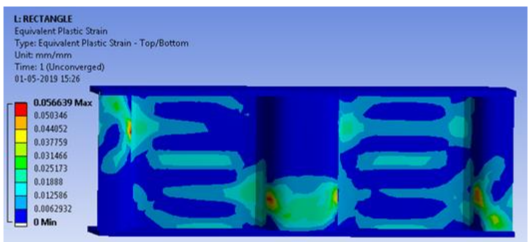


Fig. 4. Load Deflection Graph of Profile Weight Constant

B. *Equivalent plastic strain*

It can be seen that all the strain is concentrated in the web region rather than in the flanges. This makes the girder safe and prevents from local buckling.



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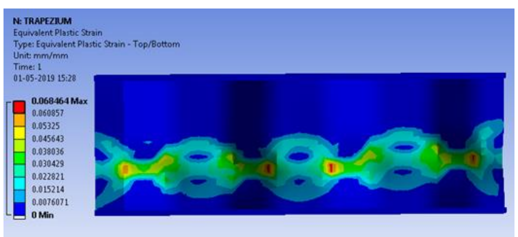

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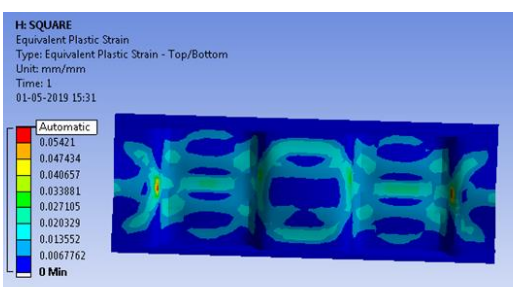

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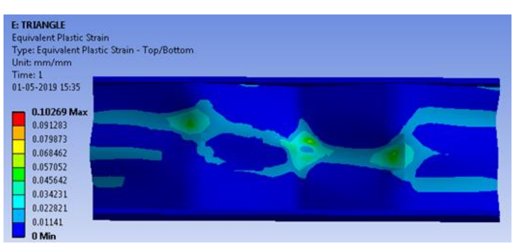

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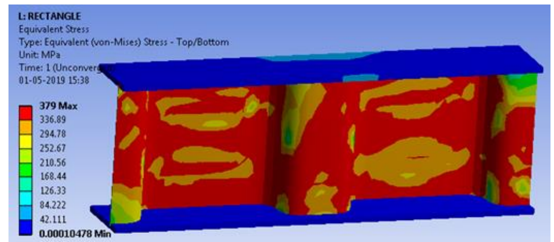
Fig. 5. Equivalent Plastic Strain Distribution of Different Shapes (i) Rectangle, (ii) Trapezium, (iii) Square, (iv) Triangular

C. *Stress distribution*

Von – Mises stress distribution of 4 models with different shapes of corrugations in the web such as rectangular, trapezoidal, square and triangular are shown below.

From the figures it can be seen that stress is concentrated in the web region in all the cases with corrugation.



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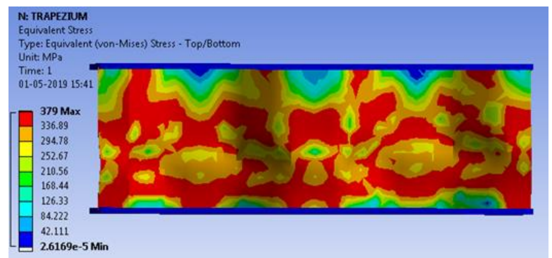

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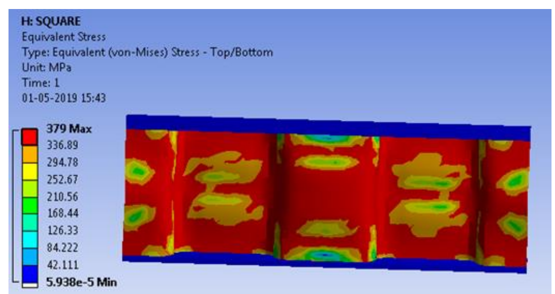

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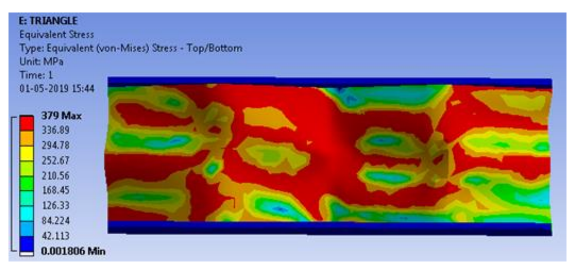

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Fig. 6. Stress Distribution of Different Shapes (i) Rectangle, (ii) Trapezium, (iii) Square, (iv) Triangular

Trapezoidally corrugated web exhibits highest stress as compared to others from the profile weight as constant study. So the acceptable method is keeping the weight of corrugations as constant.

D. *Comparison of shape study*

Comparison of shape study in terms of profile wave as constant and profile weight as constant are shown in table 2 and table 3. Load, deformation, weight of all the four different shapes are illustrated.

Table 2
Profile Wave Constant

Profile Wave Constant				
Shape	Load (kN)	Percentage	Deformation (mm)	Weight (kg)
Triangle	3001.8	1	24.13	37.77
Trapezium	3835	27.76	26.91	40.19
Square	3897.5	29.84	34.99	44.18
Rectangle	4210.6	40.27	30.77	44.18

Table 3
Profile Weight Constant

Profile Weight Constant				
Shape	Load (kN)	Percentage	Deformation (mm)	Weight (kg)
Triangle	3609	9.264	34.72	40.91
Trapezium	3835	16.11	26.91	40.19
Square	3813.2	15.44	27.17	40.51
Rectangle	3303	1	26.74	40.51

Load and deformation of all the four shapes are compared in terms of bar chart is shown in fig. 7 and fig. 8.

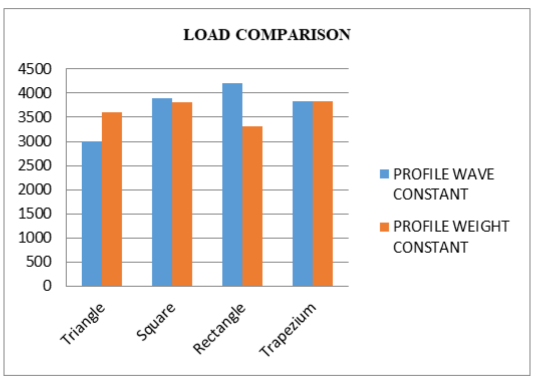

Fig. 7. Load Comparison of Shape Study

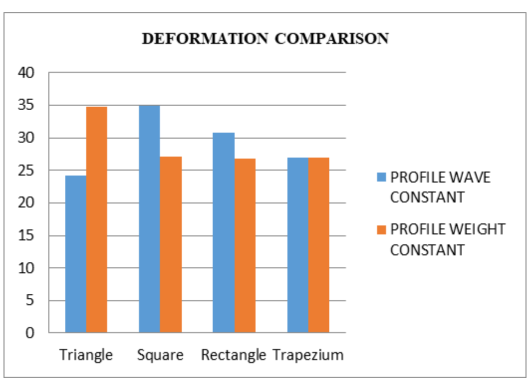

Fig. 8. Deformation Comparison of Shape Study

7. Conclusion

Ultimate load behavior of girders with different shapes of corrugations in the webs were examined in this study. The corrugated steel web itself provides the shear capacity of the girders where the shear strength is controlled by buckling and or steel yielding of the web. The flanges provide only the boundary supports for the web. In this study trapezoidal 3corrugation exhibits highest load carrying capacity than others and stress distribution too. Deformation is less for trapezium as compared to others. The proposed method has been shown capable of predicting load, deformation behavior of girders with corrugated webs to an acceptable accuracy.

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