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Effect of Different Geometries on Fatigue Life of Existing Corrugated Girders

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***Abstract:*—Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. Fatigue analysis may be of 3 types ie., stress life, strain life and fracture mechanics. Strain life is concerned with crack initiation. Stress life is concerned with total life. It does not distinguish between crack initiation and propagation. Fracture mechanics starts with an assumed crack of known size and determines growth of the crack. The paper consists of a study on the effect of different geometries on fatigue life of existing corrugated girders is studied using ANSYS workbench. Trapezoidally corrugated girder was found to have better performance than rectangularly corrugated girder.**

Keywords*—*Trapezoidally corrugated girder, rectangularly corrugated girder, strain life, fracture mechanics

I. INTRODUCTION

A girder bridge is a bridge that uses girders as the means of supporting the deck. A bridge consists of foundation, superstructure and deck. The characteristic high out-of-plane stiffness of corrugated steel web reduces the web buckling problem. Hence it does not need the use of transverse stiffeners for reinforcement, which in turn decreases fabrication costs in steel plate girders. Bridges are subjected to repeated loadings during service life causing fatigue failure. Fatigue is the progressive and localized structural damage that occurs when a material is stressed repeatedly. The simultaneous action of cyclic stress, tensile stress, and plastic strain causes fatigue damage. The plastic strain resulting from cyclic stress initiates the crack. The tensile stress promotes crack growth (propagation). The stress distribution depends on the influencing factors such as corrugation angle, flange thickness and weld defects. The present study aims to investigate the effect of different geometry on fatigue life of existing corrugated girders.

II. LITERATURE REVIEWS

Sherif A. Ibrahim, Wael W. El-Dakhakhni & Mohamed Elgaaly, (2006): In this study, an analytical technique based on fracture mechanics was proposed to determine the fatigue life of the girders. Two sources leading to fatigue cracking were isolated; one is dependent on the radius of curvature between the web folds and the other depends on the inclination angle of the inclined fold. Plate girders with sinusoidally corrugated webs have lower capacity than the corresponding plate girders with trapezoidally corrugated webs.

John Leandera, Mohammad Al-Emranib (2016): The number of cycles in each subset has an influence on the accumulated number of cycles to reach a critical crack depth. A large number of cycles allocated in each subset of the spectra will give a different result than a small number of cycles in each subset.

Kornel Kiss, Laszlo Dunai (2002), In this paper, fracture mechanics based analysis is done. An initial crack is assumed and the gradual growth of this cack to a critical size is simulated.

III. NUMERICAL PROCEDURES

A. General description of analytical method

The analysis of bridge was conducted by Finite element tool ANSYS Workbench. In this research, the effect of different geometries (rectangular, trapezoidal) on fatigue life of corrugated girder is studied.

B. Analytical model of girder

Girders with spans 4.4m were studied for different loads (low, medium and high)

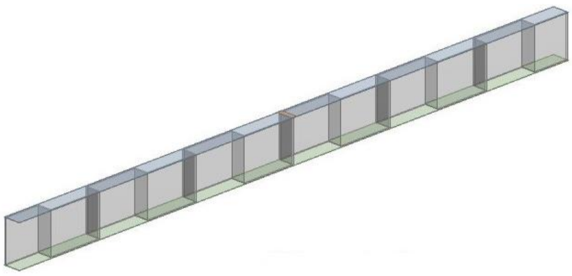

Fig 1: Girder with rectangular corrugations

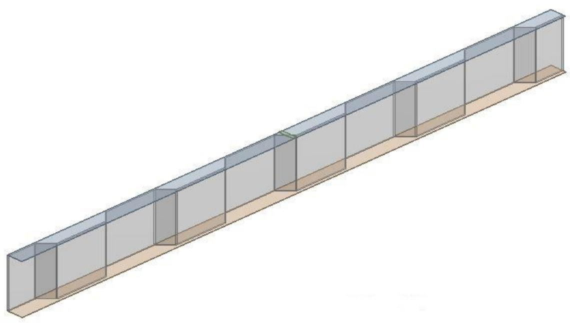

Fig 2: Girder with trapezoidal corrugations

The study include analysis of two types of web corrugations-trapezoidal and rectangular. Breadth of flange adopted is 80 mm, thickness of flange is 6mm, thickness of

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web is 8 mm, depth of web is 300 mm, corrugation length is 400 mm. Both ends of the girder were simply supported

The FE models are shown in Figure 1, Figure 2

Material properties of the girder are shown in table 1.

TABLE 1: Material properties of the girder

Material	Yield Stress (MPa)	Poisson's ratio
Structural steel	250	0.3

IV. RESULTS

The girders were analyzed in ANSYS Workbench. Static structural analysis is carried out and the results are interpreted.

I. The effect of different corrugations on fatigue life of girders

Case 1: Girder with rectangular corrugations

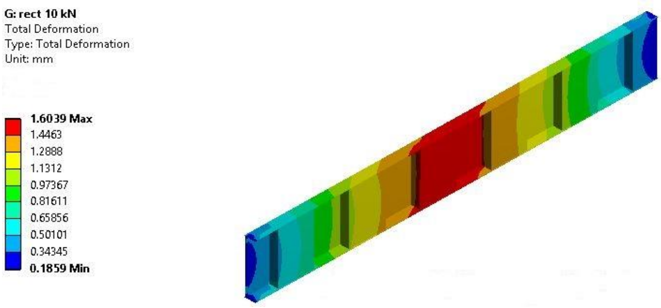

Fig 3: Deflection of the girder with rectangular corrugations (low loading rate)

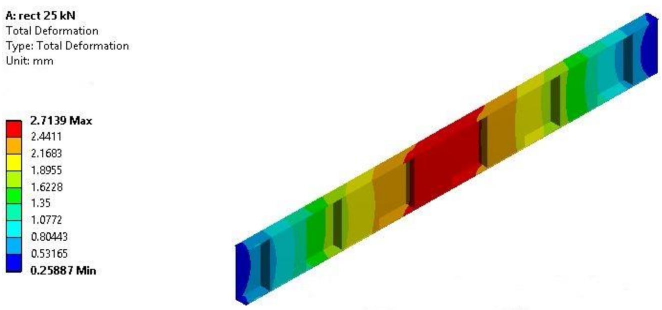

Fig 4: Deflection of the girder with rectangular corrugations (medium loading rate)

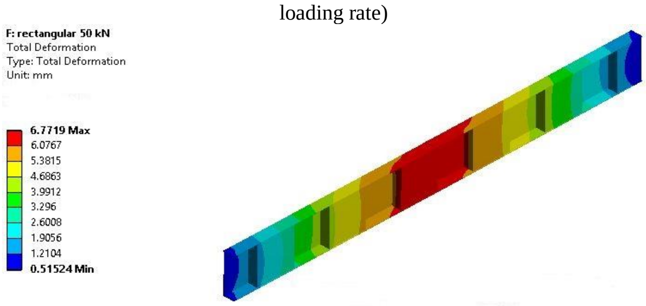

Fig 5: Deflection of the girder with rectangular corrugations (high loading rate)

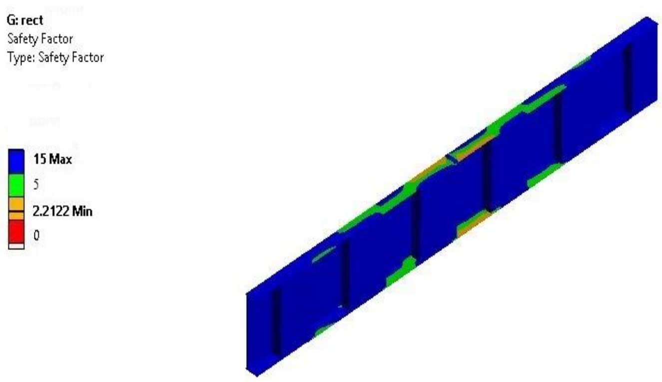

Fig 6: Safety factor of the girder with rectangular corrugations (low loading rate)

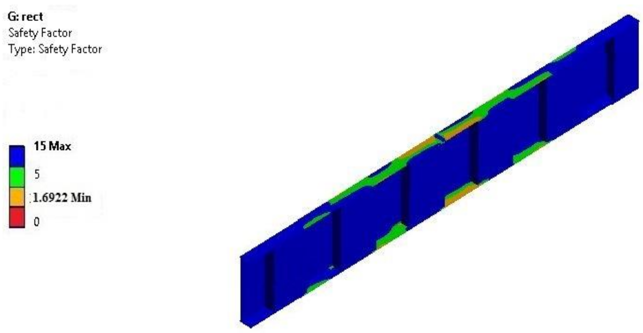

Fig 7: Safety factor of the girder with rectangular corrugations (medium loading rate)

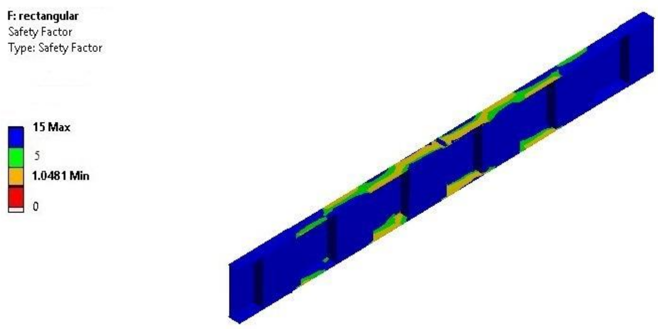

Fig 8: Safety factor of the girder with rectangular corrugations (high loading rate)

Case 2: Girder with trapezoidal corrugations

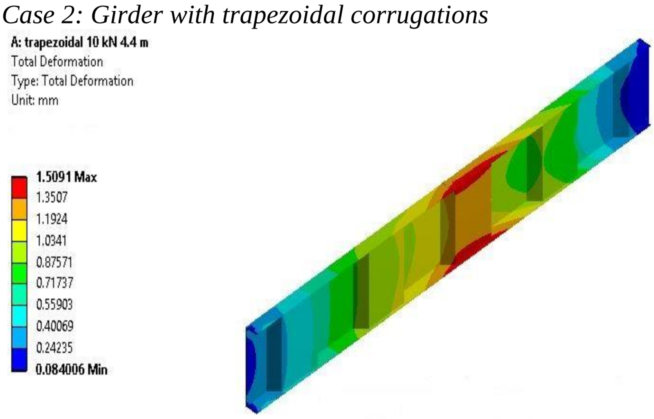

Fig 9: Deflection of the girder with trapezoidal corrugations (low loading rate)

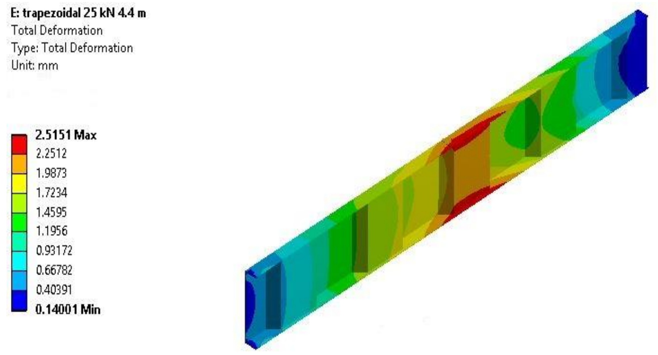

Fig 10: Deflection of the girder with trapezoidal corrugations (medium loading rate)

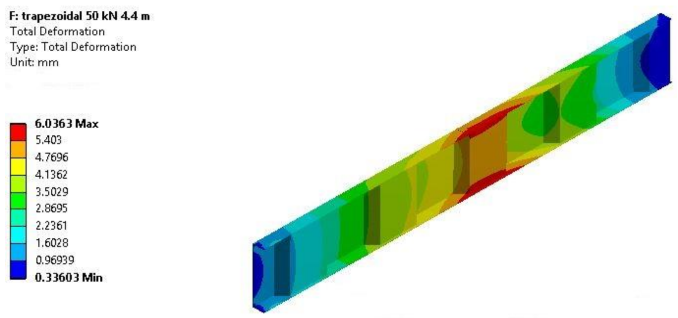

Fig 11: Deflection of the girder with trapezoidal corrugations (high loading rate)

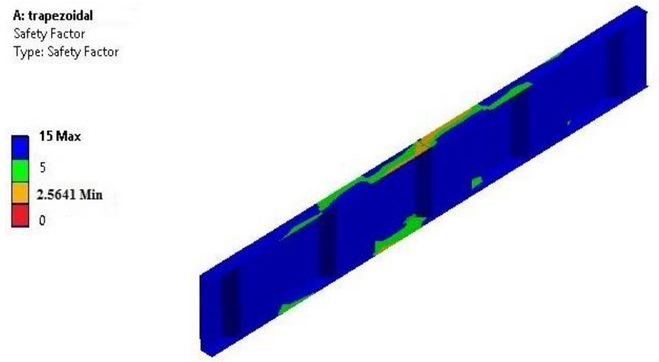

Fig 12: Safety factor of the girder with trapezoidal corrugations (low loading rate)

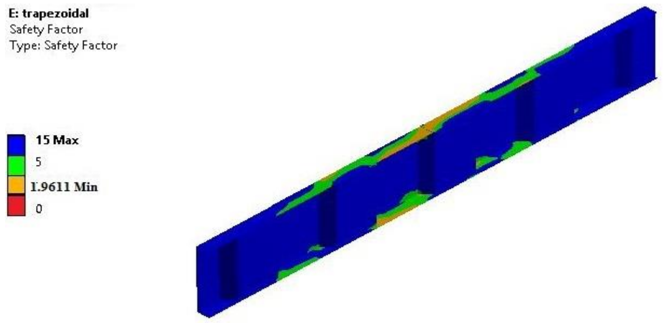

Fig 13: Safety factor of the girder with trapezoidal corrugations (medium loading rate)

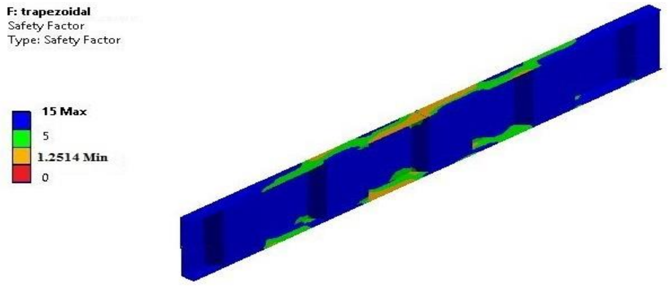

Fig 14: Safety factor of the girder with trapezoidal corrugations (high loading rate)

TABLE 2: Analysis results of girder with different web corrugations for low loading rate

Corrugation type	Life (no of load cycles)	Safety Factor	Stress (MPa)	Total Deformation (mm)
Rectangular	2.0704e8	2.2122	75.805	1.6039
Trapezoidal	2.6143e8	2.5641	59.695	1.5091

TABLE 3: Analysis results of girder with different web corrugations for medium loading rate

Corrugation type	Life (no of load cycles)	Safety Factor	Stress (MPa)	Total Deformation (mm)
Rectangular	1.624e6	1.6922	150.38	2.7139
Trapezoidal	3.6201e7	1.9611	126.02	2.5151

TABLE 4: Analysis results of girder with different web corrugations for high loading rate

Corrugation type	Life (no of load cycles)	Safety Factor	Stress (MPa)	Total Deformation (mm)
Rectangular	1.7032e5	1.0481	331.26	6.7719
Trapezoidal	1.7535e5	1.2514	265.31	6.0363

V. CONCLUSIONS

The finite element based fatigue assessment of corrugated steel web girders was performed in this study. The fracture mechanics analysis was performed in the prediction of fatigue life required for the crack to propagate through the flange thickness. The conclusions of this study are summarized as following.

1. Stress concentration factor (SCF) is found to be low for trapezoidally corrugated girder.
2. Fatigue life of trapezoidally corrugated girder increases by 10-20% than rectangularly corrugated girder. This may be due to lower value of SCF for trapezoidally corrugated girder

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3. The value of stress for trapezoidally corrugated girder decreases by 12-18% than rectangularly corrugated girder.
4. Trapezoidally corrugated girder was found to have better performance under fatigue loading than rectangular corrugated girder
5. For fatigue safety factor, values less than one indicate failure before the design life is reached. For high loading rate, the rectangular girder may fail in fatigue before design life as the safety factor is nearly having a value of 1

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