Research Article

Design of Plate Girder with Corrugated Web

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Abstract: The corrugated steel plate is to increase the shear capacity of the web of large plate girders. Present paper deals with the calculation of buckling strength of a plate girder considering rectangular, trapezoidal and sinusoidal web plate. The finite element analysis of the plate girder is carried out using ANSYS software. The results obtained from analysis are then compared with the plate girder with plane web of uniform depth. The result of Finite Element Analysis conducted as part of this investigation suggest that the strength is overestimated, at least in part because of the shear behavior to the presence of imperfections in the web.

Keywords - Corrugated, Sinusoidal, ANSYS, buckling strength, Finite Element Analysis, Plate girder.

I. INTRODUCTION

A beam is made up of steel plate and shape is connected together with the help of bolt to form a beam. It can support large loads acting on longer span. A bolt has angles and cover plates. Stiffeners are secondary plate which is attached to beam web. Cold formed steel is made by rolling into finished goods. Cold formed steel is less in weight and has high strength. Cold formed steel is used in bridges etc. Cold formed steel sheet thickness varies from 0.0147 in.(0.373mm) to 1/4 in.(6.35mm) Stiffeners, plates or angles, may be attached to the girder web by welding or bolting to increase the buckling resistance of the normal flat web. Stiffeners are also required to transfer concentrated forces of applied loads and reactions to the web without producing local buckling. Stiffeners are secondary plates or sections which are attached to beam webs or flanges to stiffen them against out of plane deformations.

Corrugation is a series of parallel ridges. Corrugated steel is used for roofing and sidings in building because they are strong and lightweight etc.

Many cases they are used as shear diaphragms to replace conventional bracing and to stabilize entire structures or individual members such as columns and beams. Typical corrugated metal in the form of pipe culvert is used in highway systems. Other forms of corrugated steel products are used in retaining walls, guardrails, conveyer covers, aerial conduits, etc.

II. DESIGN

A. Assumed data

Length of span	L = 8000mm
Thickness of flange	t_f = 12 mm
Thickness of normal flat web	t_w =20mm
Thickness of web for corrugated	t_w = 16mm
Depth/ Total height	h = 1024mm
Depth of Web	d = 1000 mm
Modulus of Elasticity	E = 2.1×10^5 N/mm^2
Width of Flange	b_f = 250mm
Shear modulus	G = E / 2(1+υ) = 8.1×10^4 N/mm^2
Poisson ratio	υ = 0.3
Coefficient of linear thermal expansion	α =12×10^{-6} /°c

B. Manual design of normal flat web

Assume live load = 10kN/m
(For heavy duty structures as per IS 875 Part 2)

Dead load =16 kN/m
Assume Industrial height =10m
Terrain category 1 of class B.
Let us consider span of industrial building =16m
Wind ward angle is 0 and for rafter slope 21.8
Assume rise =16m
Building with medium permeability C_{pe} = ±0.5 [IS 875 Part 3, Clause 6.2 3.2
[Based on building opening 5 to 20%of wall area] Spacing of purlin=1.3m (assume)

Wind load = 2068.75*1.35
= 2.792kN/m
= 2.8kN/m

Total load = 16+2.8+10
= 28.8kN/m

Factored load = 1.5* 28.8
= 43.2kN/m

Moment M_u = $Wl^2/8$
= $(43.2*8^2)/8$
= 345.6kNm

Shear force V_m = Wl/2=43.2*8/2
= 172.8kN.

$(d/67) = t_w$ = 1000/67
= 14.92<20m

Hence safe and used.

(b/t_f) = 20/12
= 1.67<13.6

Let us provide flange to be under semi compact category.
From IS 800 table 2

$A_f = 12t_f$

$(t_f) = 12t_f^2$

$t_f = 11.3 \leq 12mm$

Let us provide 250*10mm plate for flanges and 1000*12mm plate for web.
Referring to clause,10.5.5 of IS800:2007

Min. weld length = 40mm
Maximum spacing between effective length =12(t)
=240mm

Let us use 40mm weld with a gap of 200mm
δ = 3.57mm
δ = 3.57<40mm

Hence safe

C. Design of Trapezoidal plate girder

Assume live load = 10kN/m
(For heavy duty structures as per IS 875 Part 2)

Dead load = $(2(A_f)+A_w)*L*77$
= [2*0.0025+0.016] . *8*77
= 12.932kN/m

Wind load = -2068.75*1.35

	= -2.792kN/m
	= 2.8kN/m
Total load	= 12.932+2.8+10
	= 25.87kN/m
Factored load	= 1.5*25.8
	= 38.6kN/m
Moment M_u	= $Wl^2/8$
	= $(38.6*8^2)/8$
Shear force V_m	=Wl/2
	= 38.6*8/2
	=154.4kN

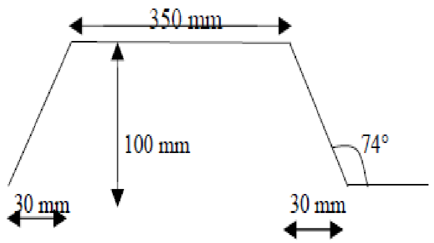

Fig. 1 Design of trapezoidal corrugation

D. Design of Sinusoidal plate girder

Load, moment and shear as per trapezoidal plate girder

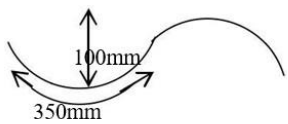

Fig. 2 Design of sinusoidal Corrugation

No. of corrugations	= 22
No. of a_0	= 11
No. of a_1	= 11

Cross sectional area A		= 2BH+Hb
		=(2x250x100) + (1000x16)
		= $156000mm^2$
Mass M		= A_1
		= 156000 * 8000 * 8.05 * 10^{-6}
	M	= 33230Kg
Moment of Inertia I_{xx}		= $H^3b/12 + 2(h^3B / 12 + hB (H+h)^2 / 4)$
		= $2.86x10^9mm^4$
	I_{yy}	= $b^3H/12+2(B^3h/12)$
		= $3.15x10^7mm$

Section modulus S_{xx} $= 2I_{xx}/(H+2h)$

$= 5.6x10^6 mm^3$

$S_{yy} = 2I_{yy}/B$

$= 2.52x10^5 mm^3$

Radius of gyration r_x $= (I/A)^{0.5}$

$= 369.62mm$

$r_y = (I_y/A)^{0.5}$

$= 38.7mm \sim 40mm$

Centre of gravity X_{cog} $= B/2$

$= 125mm$

$Y_{cog} = ((H/2)+h)$

$= 512mm$

$= 0.92$

Compression flange C $= (b-t_w-2r) / 2$

$= 77mm$

$C / t_f = 6.42mm$

$= 9 x 0.92$

$= 8.28$

$C / t_f < 9 \varepsilon$

$6.42 < 8.28$

The flange in compression in class 1

$d/t_W = 62.5$

$= 72 \times 0.92$

$= 66.24$

$d/t_W < 72 \varepsilon$

The web in bending is class 1

$\gamma M2 = 1.25$ (Joint plate in bearing) (EN 1993-1-1) Note 2-B

The shear buckling resistance for web should be verified according to section5 of EN1993-1-5

$h_W/t_W > 72$

$1000/16 > (72x0.92)/1.25$

$62.5 > 52.99$

Hence safe against buckling

$M_{Ed} / M_{C,Rd} = (308.8)/1.06\times10^4$

$=0.03 <1.0$

Hence safe against bending

$V_{Ed} / V_{sc,Rd}$ $\underline{< 1.0}$

$(169.2) / 2564$ $\underline{< 1.0}$

$0.07 < 1$

Shear resistance of the section is adequate

The connection between flange and web is weld connection

$\delta < span / 200$

$\delta = WL^4 / 384EI$

$= 3.41 mm$

$Span / 200 = 40mm$

$3.41mm < 40mm$

Hence safe against deflection

E. Design of Sinusoidal plate girder

Buckling for trapezoidal, τ_{cr}, l =35.30 × 10^5 N/mm^2

Buckling for sinusoidal, τcr,l = 10.26 x 10^5N/mm^2

By comparing the buckling strength of the trapezoidal and sinusoidal, sinusoidal have high buckling strength than trapezoidal.

Shear stress For Trapezoidal τ_{crl}, s = 5710 N/mm^2

Shear stress For Sinusoidal τ_{cr}, s = 9288 N/mm^2

By comparing the shear stress of the trapezoidal and Sinusoidal, sinusoidal in more efficient than Trapezoidal corrugation.

Hence in all aspects sinusoidal is more effective than the trapezoidal corrugated web and normal flat web.

The following table 1 compares the properties of the different web types and their performance in buckling, shear and deflection.

CONCLUSION

In normal plate girder for increasing load we use intermediate stiffeners, thereby the self-weight of the girder gets increased. In order to rectify this problem, we use corrugated web without increasing the self-weight of the girder. From the theoretical analysis, ultimate load bearing strength is higher in plate girder with corrugated web when compared with the plate girder without corrugated web and without intermediate stiffener. Hence corrugated plate girder is economical in all aspects.

TABLE 1 COMPARISON OF PROPERTIES

WEB TYPE	***BUCKLING (N/mm^2)***	***SHEAR (N/mm^2)***	***DEFLECTION (mm)***
FLAT WEB	11.39	199	3.6
TRAPEZOIDAL CORRUGATED	3520	5710	3.4
SINUSOIDAL CORRUGATED	126000	39288	3.4

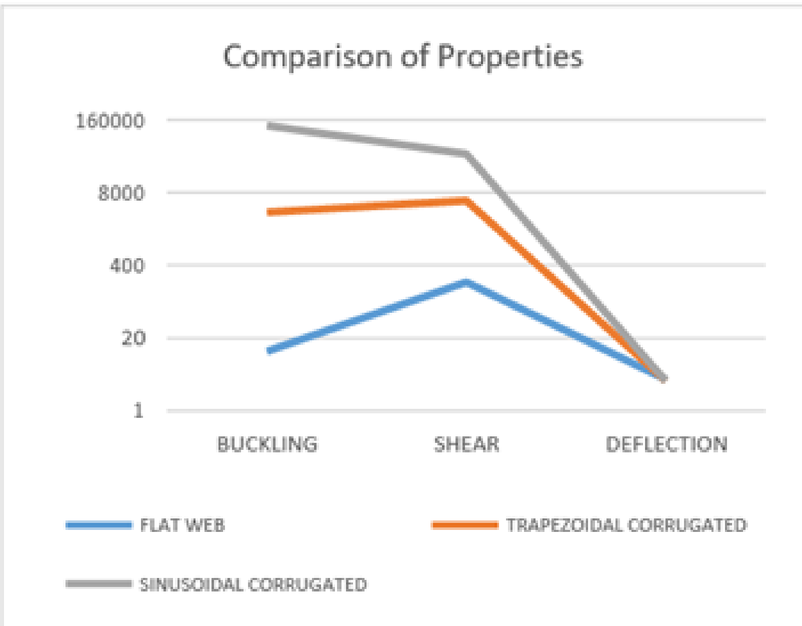

Fig. 3 Comparison

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