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COMPARISON BETWEEN BUCKLING ANALYSIS OF TAPERED WEB & CORRUGATED WEB

Taware J.P*, Kulkarni S. K

* Civil / Structure Department, Trinity College of Engineering & Research, Pune - , Pune University, INDIA

Civil / Structure Department, Trinity College of Engineering & Research, Pune - , Pune University, INDIA

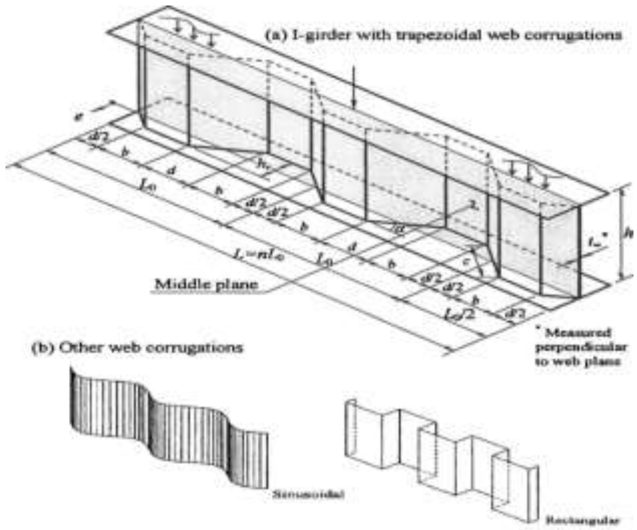
ABSTRACT

To increase the shear capacity of web of large steel plate girders, the web with different patterns such as tapered web, haunches, corrugation of different shapes are used. The corrugated steel plate is widely used structural element in many field of application because of its numerous favourable properties. Tapered (varying depth) web is one of the new technique proposed in design in order to achieve economy and to reduce its self weight . Present work is focusing on the determination of buckling strength and economy of corrugated web and tapered web. In the present study comparison has been carried out between plate girder with corrugated web beams and tapered web beams. The finite element analysis of a plate girder is carried out using ANSYS. The main aim of this project is to determine the buckling strength of corrugated web and tapered web subjected to shear for transverse loading at mid span. Also to check the economy and compare it with tapered web plate girder. Research work involves the finite element analysis of plate girder for different conditions like, i) Tapered Web beams ii) Corrugated Web Beams with Rectangular ,Trapezoidal, Web Corrugations. The main comparison parameters are i) static behaviour, ii) buckling behaviour.

KEYWORDS: Plate girder, tapered web, corrugated web, finite element analysis, ANSYS, buckling strength.

INTRODUCTION

In plate girder the top and bottom flanges resist the bending moment and the deep web plate resist the shear force in the section. For making the cross section efficient in resisting in plane bending, it is required that maximum material is placed as far away from neutral axis as possible[1]. As we know, plate girders have the maximum moment carrying capacity than any other rolled sections. To carry the moment's section has to be slender and the slender sections are susceptible to web buckling. So the web loses its buckling strength. Hence to avoid this buckling and to gain maximum strength we are focusing on providing corrugations to the web. A corrugated web is a built-up beam with thin walled corrugated web. The use of corrugated webs is a potential method to achieve adequate stiffness and shear buckling resistance without using stiffeners. This paper presents the comparison between buckling strength of hot rolled steel beam with tapered web and corrugated web beam with rectangular corrugated web and trapezoidal corrugated web having 30º corrugation. The most commonly used corrugation profile for corrugated web plates is the trapezoidal profile for which the main geometric to have the same width (in other words, $a = b$ and $d/b = \cos\alpha$). Also tapered web member can be shaped to provide the maximum strength and stiffness with the minimum weight. In this paper plate girder with maximum depth at centre and (1/2 of maximum height) tapered at support is studied.



OUTLAY OF THESIS

In this paper the models of finite element of tapered web and corrugated webs are developed and analysis is performed by using ANSYS software.

In this study following are the cases taken into account,

1. Compare the static displacement of tapered web beams (variation in length) and corrugated web beams with trapezoidal and rectangular corrugation.
2. Compare the displacement after buckling, buckling load of tapered web and corrugated web with trapezoidal and rectangular corrugation.
3. Compare the weight of tapered web and coorugated web of rectangular corrugation.

MODELLING OF PLATE GIRDER

Problem statement :

1. To determine the buckling strength of tapered web and corrugated web subjected to shear for transverse loading at midspan by finite element method "ANSYS"
2. Weight comparison and
3. To check the economy

Geometry:

Geometric dimension of tapered plate girder:-

Web height at support (hmin)	Web height at center (hmax)	Web thk. (t_w)	Flange width (b_f)	Flange thk. (t_f)	Length
400mm	800mm	6mm	240mm	30mm	10000mm

Web ht. mm	Web thk. (t_w) mm	Flange width (b_f) mm	Flange thk. (t_f) mm	Corrugat^n width mm	Corrugat^n thickness mm
800	6	240	30	400	30
					40
					50
					60

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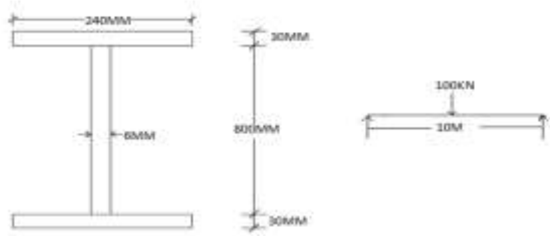

FIG. PLATE GIRDER

Maximum Bending Moment = $\frac{w.l^2}{2} = \frac{100\ X\ 10^2}{2}$ = 250 KN.m
Shear Force = $\frac{w}{2} = \frac{100}{2}$ = 50 KN
Check for Bending Strength,
$Z_{pz} = \frac{bf.tf.(D-tf)}{2} = \frac{2\ X\ 240\ X\ 30X\ (860-30)}{2}$ = 5.98 X 10^6 mm^3.
Md = $\frac{Bb.Zpz.fy}{\gamma_{mo}}$ = 1358X 10^6 N.MM > 250 KN.m.
Hence OK
Shear Capacity of Web,
$\frac{d}{t_w}$ = 133.33 > 67ε
clause 8.4.2.1, IS 800:2007
As $\frac{d}{t_w} > 67\varepsilon$, Shear Buckling needs to be considered i.e. web is failed by Shear Buckling. Thus shear buckling resistance as per clause 8.4.1. IS 800:2007 is calculated as,
$\tau_{cr} = k_v \frac{\pi^2 E}{12(1-\mu^2)\left(\frac{d}{tw}\right)^2} = 5.35\ X\ \frac{\pi^2\ X\ 2\ X\ 10^5}{12(1-0.3^2)(133.33)^2}$
= 54.40 N/mm^2.
$\lambda_w = \sqrt{\frac{fyw}{\sqrt{3}\tau_{cr}}}$ = 1.62 > 1.2
$\tau_b = \frac{fyw}{\sqrt{3}\lambda_w}$= 56.38 N/mm^2

Shear Strength
Checking reduced cross section for shear strength (IS 800)
Factored design shear force, V, in a beam due to external actions shall satisfy

$V \leq V_d$
Where V_d = design strength
$V_d = \frac{Vn}{\gamma mo}$
Where, γ_{mo} = partial safety factor against shear failure
$V_n = V_p$
$V_p = \frac{Avfyw}{\sqrt{3}}$ Clause 8.4. IS 800:2007
Where, A_v = shear area = d t_w
f_{yw} = yield strength of web

A. Check shear strength of tapered section (at depth 1/2)
Overall depth is = 430mm,
d = 400mm, t_w = 6mm
Shear strength,
$V_p = \frac{Avfyw}{\sqrt{3}}$
$V_p = \frac{(400\ X\ 6)\ X\ 250}{\sqrt{3}}$
= 346.41 KN > 50 KN.................................. Safe.

B. Check shear strength of corrugated web depth
Overall depth is = 860mm,
d = 800mm, t_w = 6mm
Shear strength,

$$V_p = \frac{Avfyw}{\sqrt{3}}$$

$$V_p = \frac{(800 \text{ X } 6) \text{ X } 250}{\sqrt{3}}$$

= 692.82 KN > 50KN.................................... Safe.

FINITE ELEMENT ANALYSIS USING ANSYS

To carry out the behaviour of plate girder with trapezoidal, rectangular corrugated web beams and tapered web beams, a finite element analysis has been undertaken with the help of ANSYS , which is general purpose finite element program designed specifically for advanced structural analysis. To analyze any structure in ANSYS, software requires some inputs like material property, element type, proper meshing, boundary conditions to get the precise results.

Model of plate girder in ansys

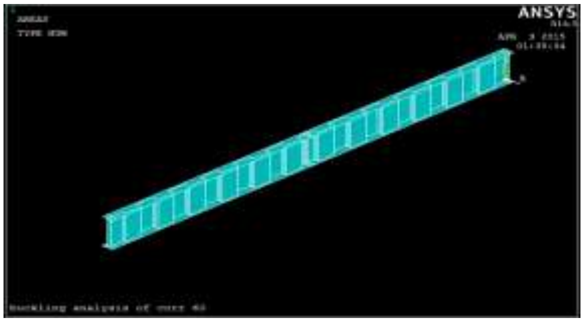

Fig. Rectangular corrugated plate girder

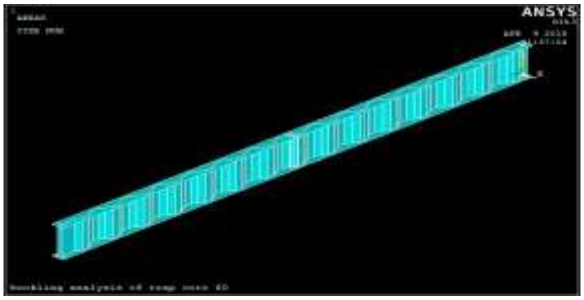

Fig . Trapezoidal corrugated plate girder

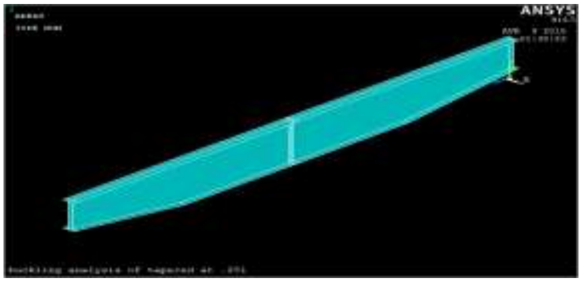

Fig . Tapered plate girder

ANALYSIS AND WEIGHT COMPARISON

Static analysis

Structural analysis is used to determine internal forces, stresses and deformation of structures under various load effect. ANSYS shows the proper initial bending shape for given loading.

Buckling analysis

Buckling is depends on loading condition and on it's geometrical and material properties. Buckling analysis gives buckling strength and buckling behaviour of girder for different modes.

Weight comparison

1 . For tapered web plate girder

Total length = 10m
d = 400mm
Web thk = 6mm.
Self weight = [2x(0.4x0.006x2.5)+(2.5x0.4x0.006)
+(0.8x5x0.006)]x7850
= 329.9 kg

2 . For rectangular corrugated web plate girder

Web thk = 6mm.
Total length = 10m
d = 800mm
Ct =30mm, Cw =400mm
Corrugation length= 25x400 +26x30 = 10780mm
Self weight = 10.78x0.006x7850x0.8= 406.19 kg

3 . For trapezoidal corrugated web plate girder

Web thk = 6mm.
Total length = 10m
d = 800mm
Ct =30mm
Corrugation length= (180x60)+(60x2)= 10920mm
Self weight = 10.920x0.006x7850x0.8= 411.46 kg

RESULT AND DISCUSSION

In case 1, static displacement comparison is carried out and it is found that the static displacement of trapezoidal corrugated plate girder is slightly more than tapered plate girder.

STATIC DISPLACEMENT				
	Tapered length(mm) / corrugation thickness(mm)			
Web	**0.25l \ 30**	**0.312l \ 40**	**0.375l \ 50**	**0.4375 \ 60**
Tapered	0.0194	0.0197	0.0201	0.0207
Rectangular	0.0336	0.0329	0.03407	0.0344
Trapezoidal	0.0369	0.056	0.0332	0.0378

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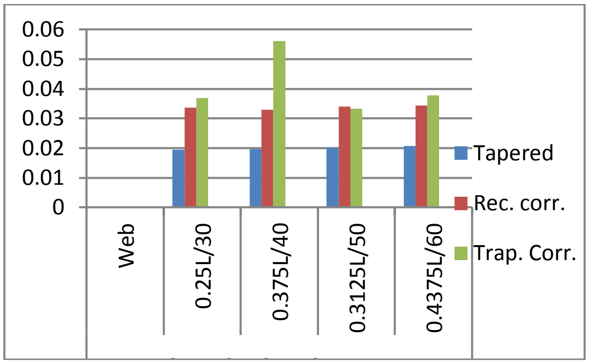
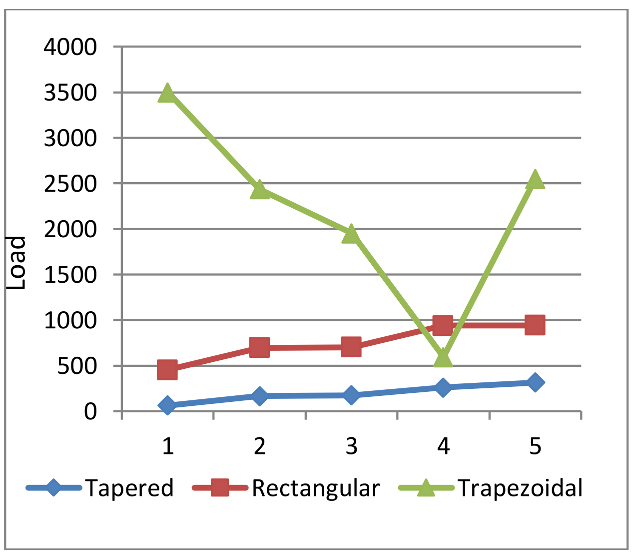


In case 2,comparison of buckling load of tapered web having length variation and it is found that 0.4375l have maximum buckling load, that buckling load compared with buckling load of rectangular and trapezoidal corrugated web.

BUCKLING LOAD FOR TAPERED WEB PLATE GIRDER (KN)				
	length variation			
Sub step	**0.25L**	**0.3125L**	**0.375L**	**0.4375L**
1	56.569	59.025	61.98	63.677
2	153.84	160.82	169.12	166.42
3	173.6	174.03	173.53	174.53
4	267.7	267.88	266.4	258.45
5	316.97	313.78	314.33	313.78

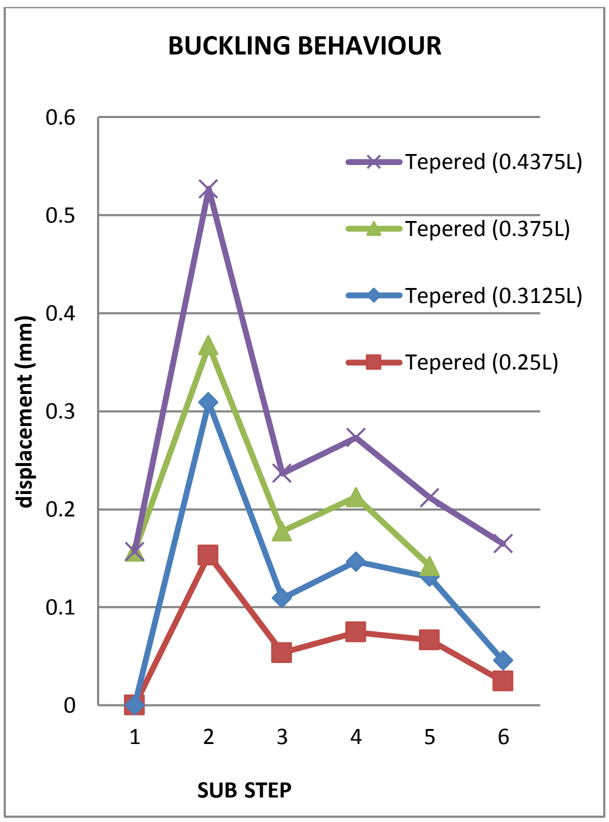
Comparison of buckling load between tapered web plate girder (0.4375l) with corrugated web plate girder (30 mm) is carried out and after comparison it is found that the buckling load of corrugated plate girder is having greater value.

BUCKLING LOAD COMPARISON (KN)					
WEB	**SUB STEP**				
	1	**2**	**3**	**4**	**5**
Tapered	63.67	166.42	174.53	258.45	313.78
Rectangular	453.35	697.25	701.43	939.09	941.22
Trapezoidal	3501	2435.1	1952.4	593.55	2547.4

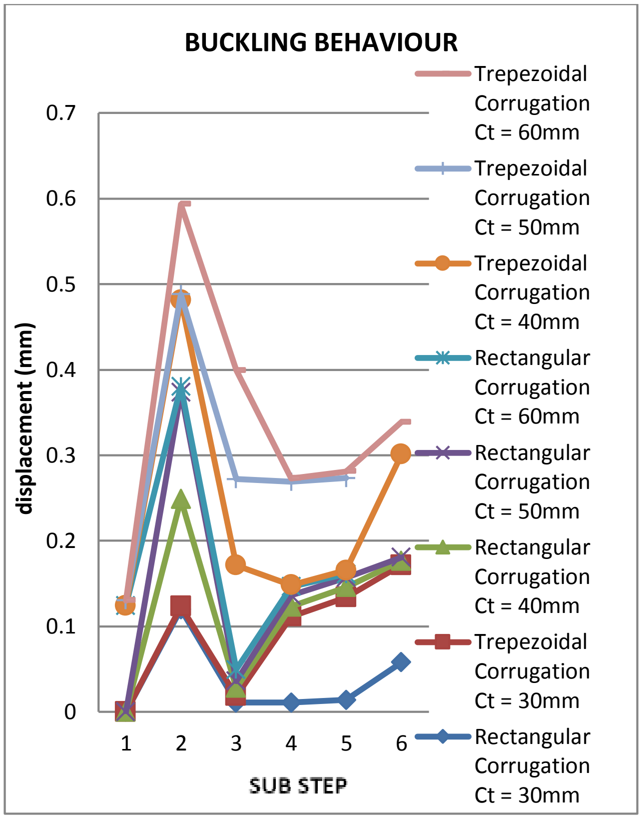


In case 3,the displacement in the direction of depth of web after buckling for tapered web and corrugated web having rectangular and trapezoidal corrugation as shown in table below.

Comparision of Buckling Behaviour												
Set	Tepered (0.25L)			Tepered (0.3125L)			Tepered (0.375L)			Tepered (0.4375L)		
	ux	uy	uz	ux	uy	Uz	ux	uy	uz	ux	uy	Uz
1	1	0.153	0.0041	1	0.156	0.00435	1	0.157	0.0045	1	0.1596	0.00464
2	1	0.0535	0.0246	1	0.0557	0.0246	1	0.0583	0.0246	1	0.0589	0.00438
3	1	0.0745	0.00268	1	0.072	0.00278	1	0.0684	0.0049	1	0.0607	0.0243
4	1	0.0665	0.00382	1	0.0645	0.00327	1	0.0658	0.00312	1	0.0695	0.00345
5	1	0.0245	0.00701	1	0.0212	0.0079	1	0.0113	0.00707	1	0.119	0.0075
Set	Rectangular Corrugation Ct = 30mm			Rectangular Corrugation Ct = 40mm			Rectangular Corrugation Ct = 50mm			Rectangular Corrugation Ct = 60mm		
	ux	uy	uz	ux	uy	Uz	ux	uy	uz	ux	uy	uz
1	1	0.12	0.02	1	0.125	0.0207	1	0.125	0.0209	1	0.1245	0.0208
2	1	0.011	0.0016	1	0.00954	0.00143	1	0.0081	0.00159	1	0.0068	0.00152
3	1	0.011	0.0031	1	0.0117	0.0029	1	0.013	0.0029	1	0.0134	0.00288
4	1	0.014	0.0034	1	0.012	0.0029	1	0.0111	0.00279	1	0.0102	0.00262
5	1	0.058	0.0044	1	0.005	0.0042	1	0.00404	0.00404	1	0.00408	0.0039
Set	Trepezoidal Corrugation Ct = 30mm			Trepezoidal Corrugation Ct = 40mm			Trepezoidal Corrugation Ct = 50mm			Trepezoidal Corrugation Ct = 60mm		
	ux	uy	uz	ux	uy	Uz	ux	uy	uz	ux	uy	uz
1	1	0.00365	0.00141	1	0.1012	0.0368	1	0.00597	0.00179	1	0.1054	0.0367
2	1	0.0077	0.0021	1	0.1218	0.0286	1	0.00641	0.00219	1	0.1271	0.02725
3	1	0.1006	0.0363	1	0.00204	0.0011	1	0.1006	0.03608	1	0.00389	0.0019
4	1	0.12	0.0291	1	0.00426	0.00108	1	0.1205	0.0295	1	0.00795	0.00357
5	1	0.1138	0.0815	1	0.1204	0.0672	1	0.1078	0.0829	1	0.0377	0.0075



Buckling behaviour of tapered web in Uy direction



Buckling behaviour of trapezoidal corrugated web and rectangular corrugated web in Uy direction

CONCLUSION

A study has been carried out to determine the buckling strength and economy of tapered web plate girder with corrugated web.

1. It is concluded that tapering the web as per profile in the present study there is not much difference in displacement & Buckling behaviour, but has the lowest displacement as compared to Corrugated Web.
2. However tapering the web reduces weight of the girder by about 18%.
3. The buckling behaviour of rectangular web with trepezoidal web showing much variation in uy direction.
4. Hence, it is concluded that trapezoidal corrugated web which is better in comparison with rectangular corrugated web.

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