iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 2017 **Issue:** onferende **Month of publication:** September 15, 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

Cold Formed Steel- Z Purlins

Kanchan S Takale[1], Prof. R.V.R.K. Prasad[2], Dr. Ramesh V Meghrajani[3]
[1]M. Tech Student, [2]Associate Professor, Structural Engineering Department, KDKCE, Nagpur
[3]Principal Consultant, NEO Infrastructure Consultants, Nagpur

Abstract: Pre-Engineered Buildings are metal building systems in which all the structural elements are factory-made and then assembled at the site in accordance to the design. In earlier days, these buildings were made from wood and later in hot rolled steel. Hot rolled steel sections have higher thickness starting form 5mm or 6 mm. This resulted in heavier design. Economy was a difficult parameter to achieve in hot rolled steel structures. Today, Pre-engineered building elements are principally made of cold form steel. Primary attractions of cold form steel are light weight, less tolerances, cheaper optimised sections, etc. Steel structures are designed to optimum value for economy. Optimised sections are more adaptable with cold form steel with regards to fabrication. Purlins are secondary members whose major structural function is to carry external loads and to transmit them to the main frame. Purlins used to be made of angle, I or C sections in hot rolled steel. In cold rolled steel, any optimised desirable shaped can be used. However, over time, C and Z sections are popularly used as purlin members. Local buckling is common in the web and the flange of the purlin section. Purlins are placed perpendicular to the flange of the rafters. Out of various sections available sections, Z purlins are more adaptable because of its torsional stability and its ease to overlap and install. This paper discusses merits of cold rolled steel over hot rolled steel and design principles of purlins, general design considerations for cross -section of purlins.
Keywords: Pre-Engineered Buildings (PEBs), Cold formed steel (CFS), Hot rolled steel (HRS), Metal building systems (MBS), Zee– purlins (Z – purlins), Slender Sections, Hot dip galvanising (HDG).

I. INTRODUCTION

The construction industry has progressed into new dimensions with regards to materials used for construction, modern architecture, method of construction, etc since the oldest civilizations. Today industry requires modern techniques to aid faster construction. Metal building systems have proved to aid this need to the exponential growth of industry. Metal buildings have gained their popularity due to its fast and easy construction, longer spans, more usable area, flexibility in property expansion and its portability. Also, in case of minor damages, the structure is easily repairable. Preservation of metal buildings is also easier and cheaper. Earlier wooden structures were famous which then begun to be replaced by hot rolled steel components in the industrial sector of the construction industry. Hot rolled steel from the last few decades are being replaced by cold formed steel. Cold form steel is nothing but hot rolled steel which is further processed at room temperature to give thin gauged optimized sections used in metal building systems.

A. Manufacturing of CFS

[18] CFS begins with the production of raw steel i.e., iron ore + small amounts of carbons. Molten steel is poured and pressured to form thin sheets of steel called "hot bands" Hot bands are then reduced to thin sheets at room temperature. Here it is called as "cold rolled steel" These strips are called as "coil". Slits are then cut out from the coil to form "slit coils" meeting the required section sizes. Desired shapes can be obtained by simply rolling the slit coil at room temperature. Unlike in HRS where high temperatures are required for rolling. Roll forming of steel is done through series of dyes. Holes for bolts and other items can be punched at the same time while rolling. This reduces installation time.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

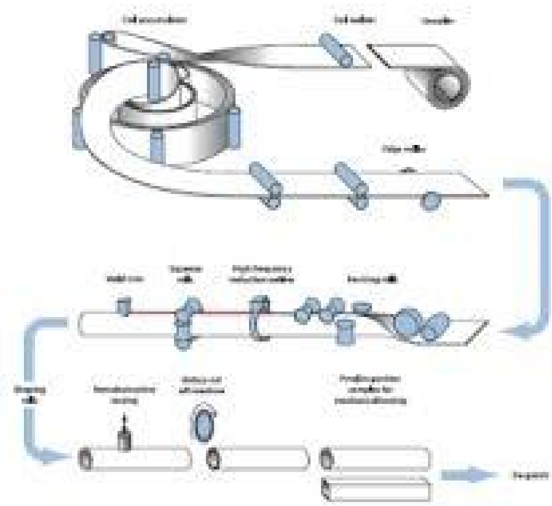


Fig - 1: Line diagram showing cold formed steel processing

Fig – 1 shows the cold rolling process of the steel. The process of making the thin metal sheet is same as the process of hot rolled steel. In cold rolling the thin metal sheet undergoes through rollers of different shapes and sizes to give the metal sheet the desired shape. Further press-brakes are used to give sharp offsets to the member is required.

B. Merits of CFS over HRS

[13]

		CFS	HRS
Design	Considerations	Local, distortional and global buckling considered	Only global buckling considered
	Span	Designed as continuous span	Designed as simply supported span
	Longer span	Purlins are nested into one another	Open web sections are fabricated
Flexibility of Shapes		Flexible and unique shapes also possible	Standard and limited shapes
Connection		Simple (Standard bolted connections. Welding is avoided)	Complicated (Variable bolted and welded connections possible)
Galvanising		Pre – galvanising possible and	Post – galvanising possible
		preferred (Thin members distort during HDG)	
Economy	Cost	Low cost of manufacturing.	High cost of manufacturing
	Span	Longer spans can be achieved by nesting members into one another.	

Table – 1: Merits of CFS over HRS

C. Classification of cross – section in HRS as per IS 800:2007

[9]In India, for the construction of steel structures, currently IS 800:2007 is being referred for HRS while IS 801:1975 is referred for CRS.

1) Class 1 (Plastic)
2) Class 2 (Compact)
3) Class 3 (Semi-Compact)
4) Class 4(Slender)

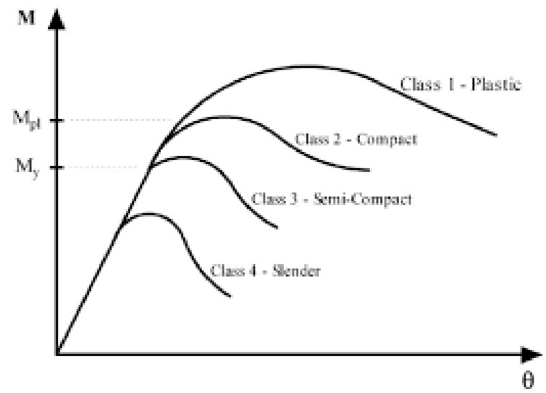


Fig - 2: Graph Showing Classification of Sections with respect to moment (M) and curvature (θ) as per IS 800:2007

From Fig - 2 we can predict that
Phase I – curve linear – section remains completely elastic
Phase II – curve non-linear – section partially elastic and partially plastic
Phase III – curve non-linear – section completely plastic
Phase IV – curve parallel to curvature – plastic hinged mechanism formed

Cold formed sections are known for their thin gauges. Since these sections have higher slenderness ratio (b/t) or (d/t), they are defined as slender sections and are referred to be designed as per IS 801:1975.

Overall depth (mm)	Width of flanges (mm)	Effective depth (mm)	Thickness (mm)	Slenderness ratio (d/t)	Slenderness ratio (b/t)
200	60	191	1.5	127.33	34
200	60	190.4	1.6	119	31.5
200	60	189.2	1.8	105.11	27.33
230	60	218	2	109	24
230	60	216.8	2.2	98	21.27
250	70	235	2.5	94	22
250	70	232	3	77	17.33

Table – 2: Slenderness ratios of z purlins available in India.

The table shows that the d/t ratio of all the available cross-sections is much higher than the limit of 42ε (Limiting width to thickness ratio given in Table 2 of IS 801:1975 for internal element of compression flange).

II. PURLINS

[10]Purlins are secondary structural members. Purlins span the distance between the primary building frames of metal building. Purlins are essential part of the roof diaphragm. Purlins carry exterior loads to main frame. Cold – formed Purlins have a wide variety of Cross – section available. Light gauge purlins of 200mm to 300 mm in depth can span 7.62m to 9.1m, and even more, depending on loading, geometry, material specifications and deflection criteria. The spacing in between the purlins is dependent on the load carrying capacity of roof panel. The concept of Z purlins was introduced by Stran-Steel Corp in 1961. In cold formed steel Z and C sections are popularly used. Z purlins has its own merits over another available cross-section. A considerable degree of continuity can be achieved in case of Z purlins. A continuous pattern can be formed by overlapping and fastening. Z sections are nested one inside another. Minimum length for the which each purlin member is about 300 mm. This lap length can be increased for longer span distances in between the main frames.

A. Selection of the cross – section of the purlins

[9] A major consideration during erection of purlins is whether to place angle, channel or zee section purlins with their flange facing up-slope or down-slope. This phenomenon is governed by the position of shear centre, area of the cross- section, availability of members and installation feasibility of the section (here lapping).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

B. Cross – sectional area of the purlins

Area is directly proportional to cost. As shown in Table – 3 for sections with constant depth the areas differ as the cross-section differs. And the area differs dramatically when the steel changes from hot rolled steel to cold formed steel. This change is observed mainly due to the sharp decrease in the thickness of the sections. It can be observed from the graph that the area with CRS is reduced by approximately 70% as compared to minimum area required with HRS.

Sr No	Shape Of Cross section	Depth	Nos	Area	Steel
		mm		mm^2	
1	L	100	2	1980	HRS
2	I	200	1	5200	HRS
3	C	200	1	3780	HRS
4	Z	200	1	540	CFS
5	C	200	1	540	CFS

Table – 3: Areas of different sections at constant depth

The above sections compared are commonly used as purlin sections in India. The areas are highlighted on the graph below. The L, I and C – sections were used in HRS. CRS has a wide variety of sections. In CRS C and Z sections are widely used. The section chosen for comparison are minimum sections available in steel table with common depth. However, for CRS sections, standard section properties are available from respective manufacturing companies. Some of them give details about cross-section properties while some give net section properties. Hence, a section in practice is used with net section properties.

It implies that overall cost of the truss is widely dependent on purlins. Optimisation of purlins can reduce the cost of the truss dramatically. For this, selection of right cross-section and its parameters such as depth of web, width of flanges and thickness of the member must be considered. An iterative design can be done for the same.

C. Importance of purlins in the economy of the structure

[9]Let s = spacing of the truss

t = cost of truss / unit area

p = cost of purlins / unit area

r = cost of roof coverings / unit area

x = overall cost of roofing system/unit area

$$\text{cost of trus} \propto \frac{1}{\text{spacing of truss}}$$

$$\text{cost of purlins} \propto (\text{spacing of truss})^2$$

$$\text{cost of roof coverings} \propto \text{spacing of truss}$$

Overall cost = OC = t+p+r then OC =

$$\frac{C_1}{s} + C_2 s^2 + C_3$$

For optimized section,

$$\frac{d(OC)}{ds} = 0$$

$$c = 2p + r$$

It implies that overall cost of the truss is widely dependent on purlins. Optimisation of purlins can reduce the cost of the truss dramatically. For this, selection of right cross-section and its parameters such as depth of web, width of flanges and thickness of the member must be considered. An iterative design can be done for the same.

III. DESIGN PRINCIPLE OF Z PURLIN

A. Simply supported span for HRS

[8]In case of HRS, purlins are designed for simply supported span. Fig – 5 shows the BM and SF coefficients of a single span simply supported beam. A simply supported span has a higher BM coefficient of 0.125 as compared to that of the continuous spans. HRS sections cannot be overlapped for continuity. They are connected with shear connector. The deflection in case of simply supported spans is more comparatively. In case of simply supported beams, no end moments coefficients are generated. Maximum moment will be shared by middle zone of the beam resulting in higher depths of the sections.

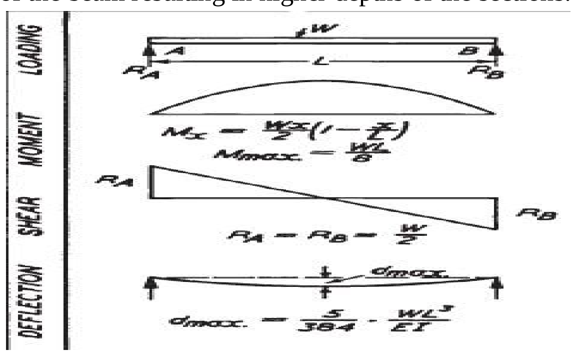


Fig – 3:imply supported beams - UDL as per Steel Designer's Manual – AISI

B. Continuous span for CRS

[8] Design principle for a purlin is similar to that of a beam. Z purlins due to its overlapping capability is designed as a continuous purlin. A continuous span analysis will avail lower values of bending moment coefficients. Fig – 6 shows the BM and SF coefficients of a 4-span continuous beam. IS 801 – 1975 do not provide any BM and SF coefficients for a continuous span as in case of AISI. The BM coefficients for span in case of a continuous beam is 0.077. At supports where the BM coefficient is -0.071 overlapping of Z purlins provides twice the cross – sectional area as that of required. In case of a simply supported beam, the BM coefficient increases to 0.125. And no Moment coefficients at end supports. Installation of sag rods further decrease the unbraced length of the purlin taking the roof system towards higher stability. It has to be noted that the end span does not have overlap of the purlins. Therefore, the purlins need to be designed for end span, intermediate span, end support and at all intermediate supports. The unbraced length for these spans will be the sag rod spacing.

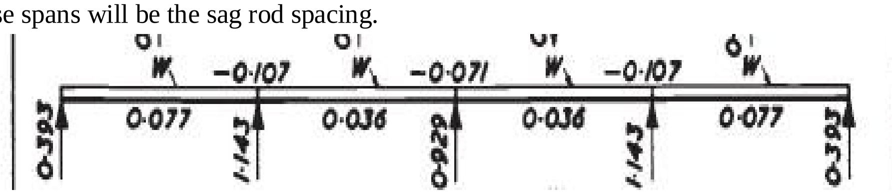
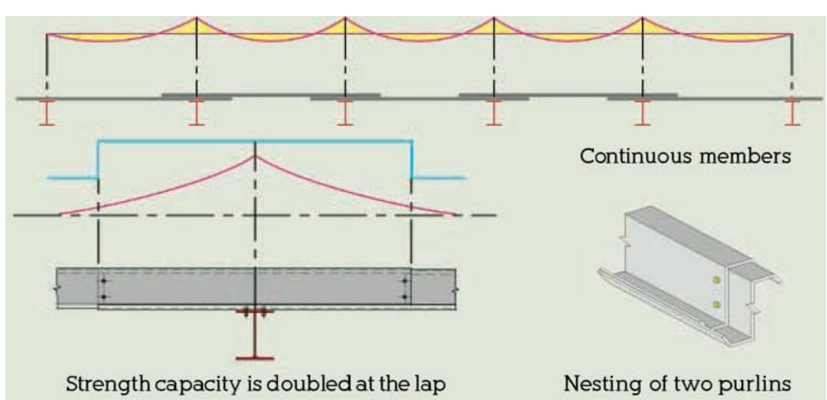


Fig - 4 Bending Moment and reaction Co-efficient - Equal span continuous beams – UDL as per Steel Designer's Manual – AISI



International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

Fig – 5: Image courtesy: (Mr. Roshan S Satpute, et. al “Building Design Using Cold Formed Steel Section”)

C. Wind Pressure

[8] Load combinations considered are

1) DL + LL (Deal load + Live load)

In this case, the gravity loads are not perpendicular to the axis of the cross-section of the Z purlin. Fig – 6 shows the top flange of the section is under compression and the bottom flange is under tension. Top flange is restrained throughout the length at regular intervals to the roof sheeting.

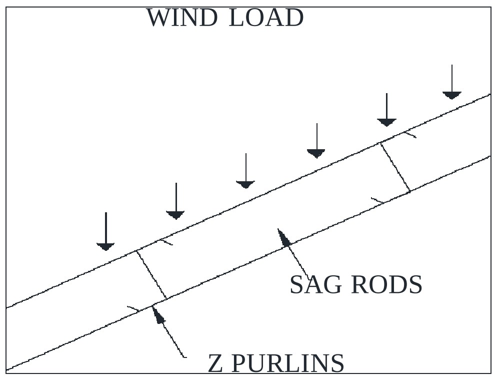


Fig - 6: Z Purlins under gravity load

2) DL + WS (Deal load + Wind Suction)

This case occurs in close as well as partially open buildings with high magnitude in later case. The wind action here is reverse to that of case 1. Fig – 7 shows the wind pressure direction under suction. Here the top flange is under tension and the bottom flange is under compression. The bottom flange is not restraint against the compressive forces except at the supports. This causes lateral torsional buckling of the bottom flange member. Greater difference in the Ix and Iy properties of the section leads to lateral torsional buckling. Hence, sag rods are used to reduce the unbraced length of the member.

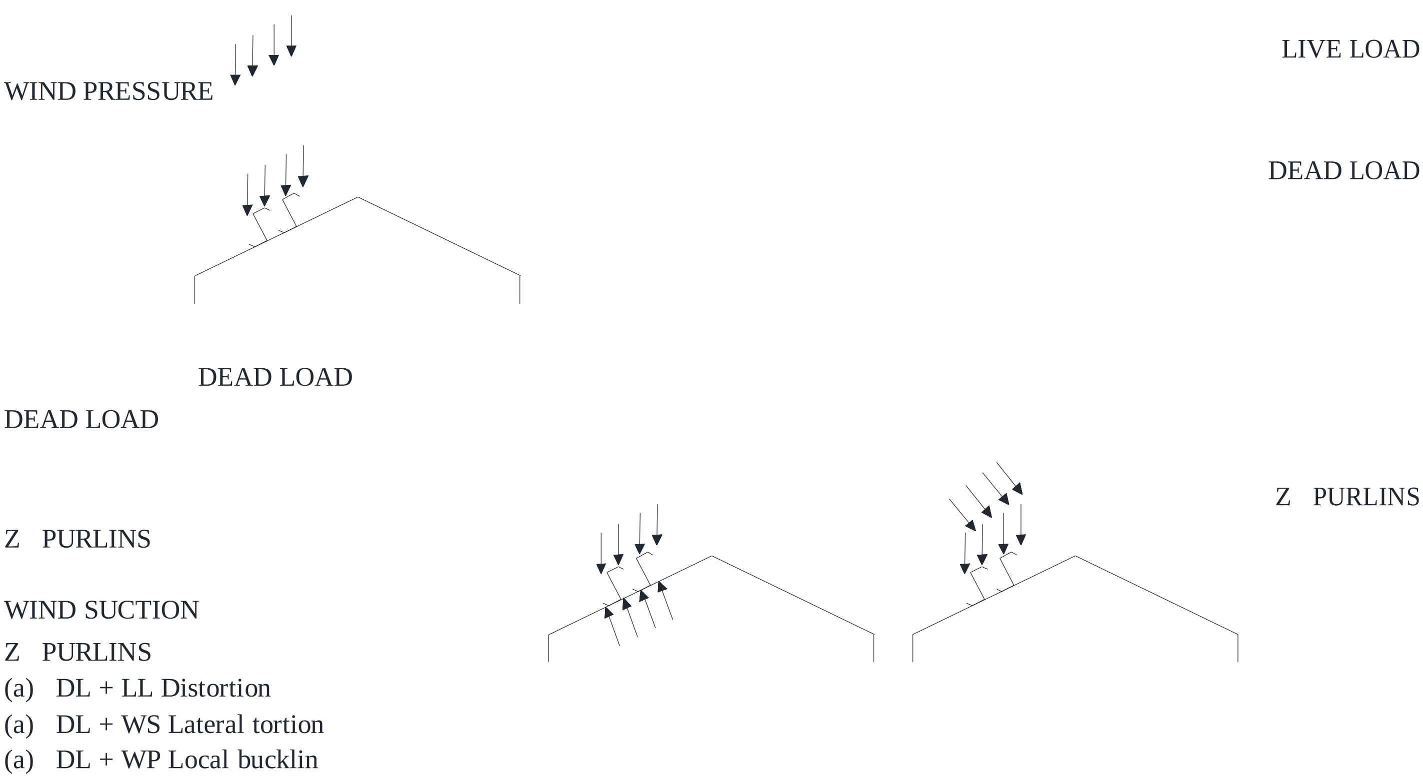


Fig - 7: Wind pressure diagrams

3) DL + WP (Deal load + Wind Pressure)

In this case also the bottom flange is under tension and the top flange is under compression. The direction of the wind here may be parallel or perpendicular to the ridge line depending upon the structural orientation. These results in local buckling of the web member. The beam here, bend sideways. To avoid this sag rods are installed connecting the webs of consecutive purlins laid over the rafter. Fig – 8 shows purlin with sag rod holes with bottom flange under compression.

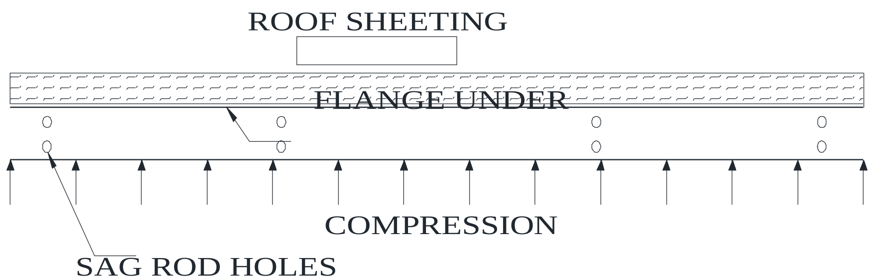


Fig - 8: Bottom flange of the purlin under compression

As shown in Fig – 8, the bottom of the roof is under compression due to the positive internal wind pressure. This compressive force is taken by the purlins. Hence, the bottom flange of the purlin being unbraced throughout fails under high compressive forces

IV. DEFORMATIONS IN Z PURLINS

Materials suitable for cold forming are slender and thus susceptible to local deformations under load. These deformations can take two forms: local and distortional buckling. Local buckling as well as lateral torsional buckling is observed in the web of the Z purlin section.

A. Local bucklng

In local buckling, the axis of the member is not distorted. The member deflects longitudinally. Fig – 9 shows local buckling in both the legs of an L section. It is to be noted that the shape of the cross - section remains undistorted.

B. Distorsional buckling

[9]Von Mises's distortional theory is applicable to purlin sections. Purlins are placed perpendicular to the outer flange of the rafter. This tilting trails to distortional buckling of the member. Distortional buckling affects the unbraced length of the bottom flange of the purlin. Lateral torsional buckling throughout the section disturbs the complete roof diaphragm leading to uneven faces on the roof and in severe cases, failure.

To restrain the flanges 1996 AISI Cold Formed Specification states that the maximum top flange lateral displacements with respect to the purlin reaction points do not exceed the length divided by 360

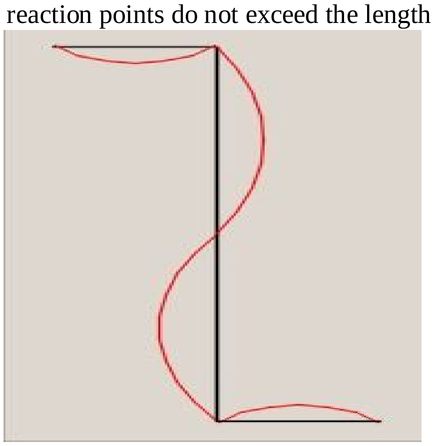


Fig 9 (a): LOCAL BUCKLING Beam deflects laterally

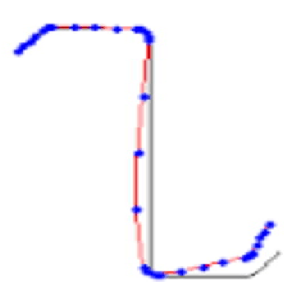


Fig 9 (b): DISTORSIONAL BUCKLING Beam twists and deflects laterally

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com

C. Lateral torsional buckling

In this case, the beam twists and deflects laterally. Fig – 10 shows a Z sections with flanges and web laterally deformed and a distorted cross section. To avoid this type of buckling sag rods are placed in the web of the purlins. Sag rods reduces the unbraced length of the purlin.

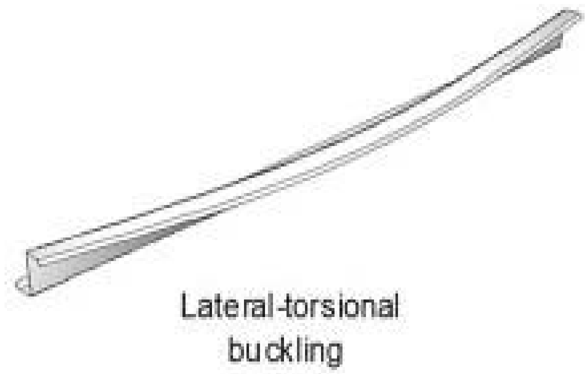


Fig - 10: Lateral torsional buckling of Z section

The various factors affecting the lateral-torsional buckling strength are Distance between lateral supports to the compression flange, boundary conditions), type and position of the loads, material properties, initial imperfections of geometry and loading, etc

V. DESIGN CONSIDERATIONS FOR CROSS SECTION OF PURLIN

[2], [3], [8]

A. Loading calculations are done as per IS 875:1987.

B. Cross – section selection.

For CRS, no handbook is available as in case for HRS. Hence, properties of the sections are calculated by traditional mathematical models. Here, b/t ratios must be checked in accordance to clause 5.2.1 of IS 801:1975.

Dimensional limits and considerations are considered as per AISI Manual.

1) *Maximum flat-width to thickness ratio* - Maximum flat-width to thickness ratio for a compression flange is 60. It can be increased with changing stiffeners provisions to compression flange. However, exceedance of w/t ratio beyond 250 develops noticeable deformation at the full design length without affecting the ability of the member to develop required strength.
2) *Maximum web depth – to – thickness ratio* - The maximum web depth – to – thickness ratio for cold formed sections with unreinforced web is limited to 150. For members which provide adequate means for transmitting concentrated loads and/or reactions into the web the web depth – to – thickness ratio is 200.
3) *Flange Curling* - The amount of flange curling should not exceed 5 percent of the depth of the section under usual conditions.

C. Moment calculations same as for continuous span beam. Imposed loads intensity governs the design of purlins. Major design parameter is depth of the purlin.

D. *Allowable design stress* - Stress on the net section of tension members, and tension and compression on the extreme fibres of flexural members shall not exceed $0.6F_y$. Where yield stress for cold rolled steel is generally 345 MPa. Other design considerations are mentioned in IS801:1975

VI. CONCLUSION

Cold formed should be used for roof diaphragms to achieve optimised sections and economy. Z purlins are most suitable sections in all parameters of design considerations. Reduced BM coefficients can be used in case of Z purlins as the overlapping of the purlins encounters the moment. Distortional buckling in Z purlins is an important factor leading to the failure of the roof diaphragms. Above studies will be useful for analysis and design of purlins.

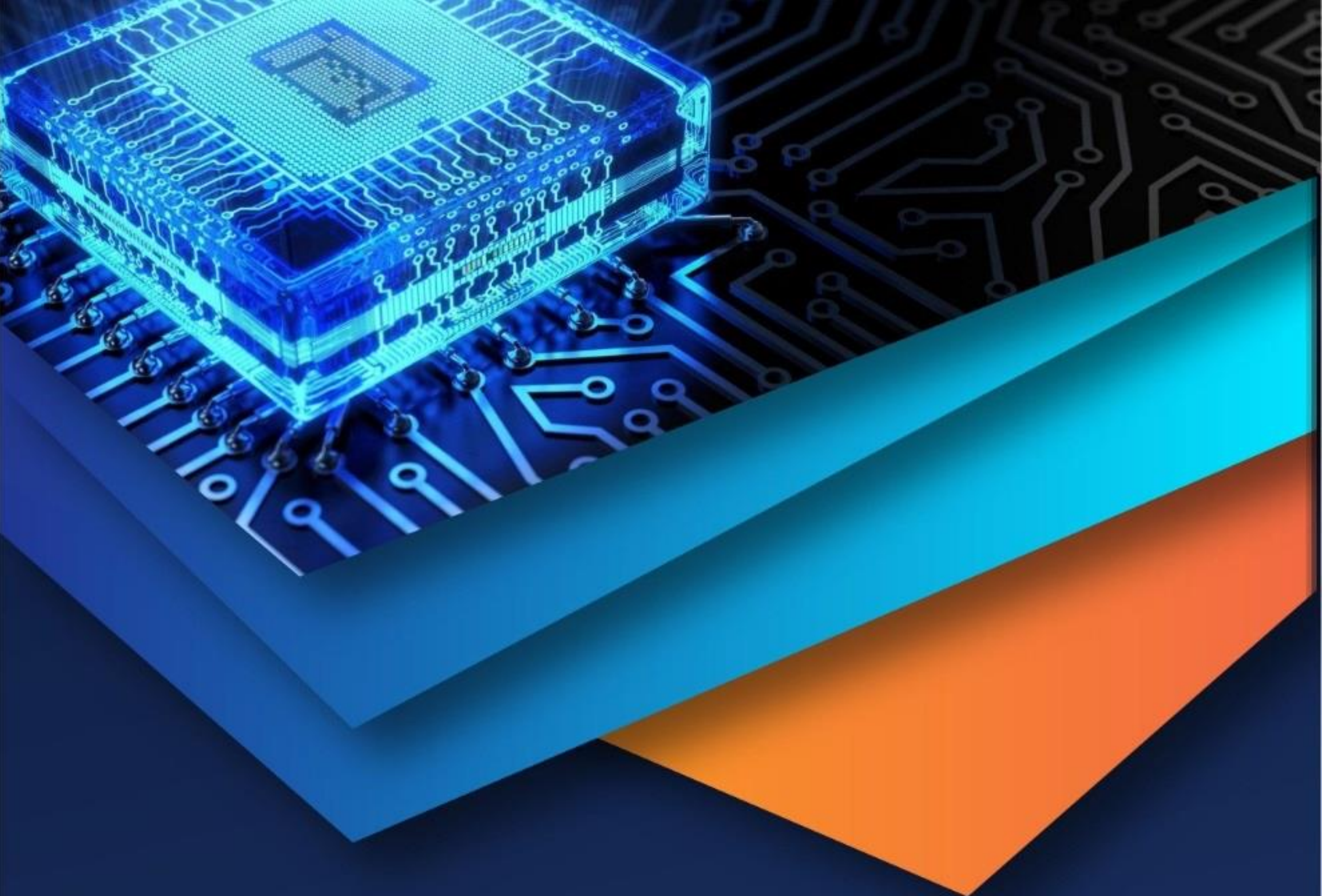
VII. ACKNOWLEDGEMENT

The author is grateful to Dr. Ramesh V Meghrajani for enlightening the core concepts in all the areas of design of PEBs. Author gives a token of thanks to the complete team of NEO Infrastructure Consultants for their cooperation. Author is thankful to Prof. RVRK Prasad for his wisdom of knowledge shared and practiced.

REFERENCES

[1] IS800:2007 Indian Standard General Construction in Steel – Code of Practice
[2] IS801:1975 Indian Standard Code of Practice for Use of Cold-Formed Light Gauge Steel Structural Members in General Building Construction
[3] IS875:2015 Indian Standard Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures
[4] IS811:1987 Indian Standard – Specification for cold formed Light Gauge Structural Steel Sections
[5] SP6 – PART 5 Handbook for Structural Engineers – Cold Formed Light Gauge Steel Structures
[6] AISC American Institute of Steel Construction - Steel Construction Manual
[7] AISI American Iron and Steel Institute - Cold Formed Steel Design Manual, 1996 Edition
[8] SCI – Steel Construction Institute - Steel Designers Manual
[9] S K Duggal "Limit State Design of Steel Structures" (Tata McGraw Hill Education Pvt. Ltd.)
[10] Newman Alexander "Metal Building Systems – Design and Specifications" Second Edition (McGraw – Hill Publications)
[11] Dr. N Subramanian "Design of Steel Structures" (OUP India), 2008
[12] Anand S , Arya Ajmani "Design of Steel Structures" edition 3, (Nem Chand),1974
[13] Mr. Roshan S Satpute, Dr. Valsson Varghese "Building Design Using Cold Formed Steel Section" published in International Refereed Journal of Engineering and Science (IRJES), Vol. 1, Issue 2 in October 2012. ISSN (Online) 2319-183X, (Print) 2319-1821.
[14] Akula Venkata Phani Manoj, Dr. S. Senthil Selvan "Flexural Behaviour of Light Gauge Cold Formed Steel Z and Hat Sections with and without Lip" published in International Journal of Civil Engineering and Technology (IJCIET), Vol. 8, Issue 3 in March 2017. ISSN Print: 0976-6308 and ISSN Online: 0976-6316.
[15] Sunil. M.Hardwani, A.V. Patil "Study, test and designing of cold formed section as per AISI CODE" published in Int. Journal of Applied Sciences and Engineering Research, Vol. 1, Issue 3, 2012. ISSN 2277 – 9442.
[16] B K Raghu Prasad, Sunil Kumar, Amaranth K "Optimization of Pre-Engineered Buildings" published in Int. Journal of Engineering Research and Applications, Vol. 4, Issue 9 in October 2014. ISSN: 2248-9622. [17]. https://sfia.memberclicks.net/about-cold-formed-steel
[17] http://engineerstandpoint.blogspot.in/2012/06/beginners-guide-to-structural.html
http://nptel.ac.in/courses/105106112/6_beams/3_behaviour_of_steel_

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 5 Issue IX, September 2017- Available at www.ijraset.com



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY