Study of Economic Aspects of Cold-Formed Steel over Hot Rolled Steel for Purlins

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Abstract
One of the great advantages of cold-formed steel (CFS) is the immense flexibility that the material affords in forming cross-sections. This flexibility would seem to readily lend itself to optimization of member cross-section shapes. Cold formed sections also having the great flexibility of cross-sectional profiles and sizes available to structural steel designers. Whereas, the low strength-to-weight ratio of hot rolled steel members leads to increase in overall load on structure as compared with cold-formed steel sections which is having high strength-to-weight ratio. In this paper focus is given on study of economic aspects of cold formed sections as purlins in comparison with traditionally used hot rolled sections for Industrial structures by using IS 800-1984 & IS 800-2007 with IS 801-1975. The most economical sections and cost comparison is presented in the paper for 5m, 6m and 8m spans with roof slopes of 10°, 15° and 20°. Similarly focus is given on the effect of sag rods in the design of purlin members.  

Keywords: Cold formed steel (CFS), Economic Aspects, Purlin, Strength-to-weight ratio and Industrial Structure.

1. Introduction
The development of cold formed sections were started during the First World War, but their popularity and rapid utilization has grown during the last few years because of their versatility and suitability for the lighter load bearing applications.

During recent period it is found that, the use of light gauge construction material has been increased worldwide. Therefore, cold-formed steel section, which has been proven to be efficient and widely used in developed countries, is a good alternative to traditional hot rolled steel.

The high strength-to-weight ratio of cold-formed steel members provide substantial savings. As a result, they have become very popular in industrial structures, where usually heavy and bulky structures are required. In such structure utilization of high strength-to-weight ratio will leads to help in reduction of the total load on structure and saving of construction time & cost. The easy availability of required shapes and sizes will help us in choosing the most economical cold-formed shape in design of structures.

To enhance the load carrying capacity of purlins, it is possible to form the shape / cross section of profile in such a way to displace the material far away from the neutral axis.

There are various shapes and cross section which can be formed easily and there is no limitation in forming the cross section of any type for column/portal, truss members, purlins / side girts & decking profiles /roofing sheet. Following are some of the typical cold formed section profiles readily available

![Sigma Purlin](image1)  
![ZED Purlin](image2)  
![C Purlin](image3)

**Figure 1:** Typical Cold Formed Section Profiles used for purlin members.
2. Advantages of CFSS:
Cold-formed steel sections are having many advantages as compared with hot rolled steel sections and timber.
The main advantages are listed as follows:
2.1 In cold formed sections high strength to weight ratio can be obtained.
2.2 Increase in yield strength of about 25% from its expected design strength due to cold forming
2.3 Minimum use of material due to use of CFS.
2.4 Versatility of profile shape available in market for CFS.
2.5 Speedy in construction and easy to erect
2.6 Consistency and accuracy of profile can easily be achieved by the use of computer control system.
2.7 Corrosion resistance by pre-galvanization or pre-coating.
2.8 Variety of connection and jointing methods are suitable for cold-formed section.
2.9 Lower in production cost and higher in profit.

3. Applications of Cold Formed Members:
The cold-formed steel section, which is regarded as steel strip with uniform profile along its length, is usually
used in load bearing application. The use of cold-formed steel section can be found in automobile industry,
shipbuilding, rail transport, and infrastructure industry. In building construction, the cold-formed steel can be
utilized in both non-structural and structural members. As non-structural members, the advantages are more on
rust resistance and aesthetic purposes. It is used as non-structural member for wall paneling, doorframes,
window frames, and services. As structural members, the usage includes roof sheeting, purlins, truss members,
beams, columns, and floor decking in steel concrete composite construction. A pointed screw system using a
hand drill is normally used for the installation of the connections.

4. Applications of Hot Rolled Members:
Various hot rolled sections used as purlin members in construction industry are I sections, Channels, equal
angles, unequal angle, T sections, circular tubes, rectangular tubes and many other fabricated sections. Generally
I sections are used for heavy load applications, whereas channel sections are most commonly used for purlin
members among all category of hot rolled sections. In this paper attempt is made to use most optimized channel
sections as purlin members.

5. Design Load Calculations:
The following loads have been considered for Design of Purlins for Strength and Serviceability as per the
Design Standards:
Dead Loads:
IS: 875 – 1987 (Part-1), Roof Sheet Load of 0.16kN/m² and Self weight of the Purlin is considered.
Live Loads:
IS: 875 – 1987 (Part-2) Specifies the live loads to be assumed in the analysis of industrial buildings as given in
table 1 below.

### Table 1: live loads for industrial buildings

<table>
<thead>
<tr>
<th>Roof Slope</th>
<th>Access</th>
<th>Live Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 10°</td>
<td>Not Provided</td>
<td>0.75kN/m²</td>
</tr>
<tr>
<td>≥ 10°</td>
<td></td>
<td>0.75kN/m² up to slope 10° and reduced 0.02kN/m² for every degree increased in slope over 10° but not less than 0.40kN/m²</td>
</tr>
</tbody>
</table>

Wind Loads:
This is the most critical load for analysis of industrial buildings. Based on the basic wind speed the total region
is divided into six zones. Here in this paper the main emphasis is given for wind zones II to VI. The Basic wind
speed, Design wind speed, Design wind pressure, External and Internal pressure co-efficient are calculated as
per IS: 875 – 1987 (Part-3) as shown in table 2 below.
Table 2: Wind load calculations for industrial buildings

<table>
<thead>
<tr>
<th>Slope of Roof (DEG.)</th>
<th>Zone (Z)</th>
<th>Basic wind speed (m/s)</th>
<th>Design wind speed (m/s)</th>
<th>Design wind pressure (Pz) (kN/m²)</th>
<th>External pressure co-efficient (Cpe)</th>
<th>Internal pressure co-efficient (Cpi)</th>
<th>Design pressure co-efficient (Cpe + Cpi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Zone - II</td>
<td>39</td>
<td>39</td>
<td>0.913</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-1.3</td>
</tr>
<tr>
<td></td>
<td>Zone - III</td>
<td>44</td>
<td>44</td>
<td>1.162</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-1.3</td>
</tr>
<tr>
<td></td>
<td>Zone - IV</td>
<td>47</td>
<td>47</td>
<td>1.325</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-1.3</td>
</tr>
<tr>
<td></td>
<td>Zone - V</td>
<td>50</td>
<td>50</td>
<td>1.500</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-1.3</td>
</tr>
<tr>
<td></td>
<td>Zone - VI</td>
<td>55</td>
<td>55</td>
<td>1.815</td>
<td>-1.1</td>
<td>-0.2</td>
<td>-1.3</td>
</tr>
<tr>
<td>15</td>
<td>Zone - II</td>
<td>39</td>
<td>39</td>
<td>0.913</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-1.1</td>
</tr>
<tr>
<td></td>
<td>Zone - III</td>
<td>44</td>
<td>44</td>
<td>1.162</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-1.1</td>
</tr>
<tr>
<td></td>
<td>Zone - IV</td>
<td>47</td>
<td>47</td>
<td>1.325</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-1.1</td>
</tr>
<tr>
<td></td>
<td>Zone - V</td>
<td>50</td>
<td>50</td>
<td>1.500</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-1.1</td>
</tr>
<tr>
<td></td>
<td>Zone - VI</td>
<td>55</td>
<td>55</td>
<td>1.815</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-1.1</td>
</tr>
<tr>
<td>20</td>
<td>Zone - II</td>
<td>39</td>
<td>39</td>
<td>0.913</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>Zone - III</td>
<td>44</td>
<td>44</td>
<td>1.162</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>Zone - IV</td>
<td>47</td>
<td>47</td>
<td>1.325</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>Zone - V</td>
<td>50</td>
<td>50</td>
<td>1.500</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>Zone - VI</td>
<td>55</td>
<td>55</td>
<td>1.815</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.0</td>
</tr>
</tbody>
</table>

Basic wind speed taken from Table-1 and the Design wind speed is calculated Assuming $K1=K2=K3= 1.0$

Design wind pressure $Pz = 0.6 \times Vz^2$ where $Vz =$ Design Wind Speed

External Pressure Co-efficient are taken from Table -5, Assuming $0.5 \leq h/w \leq 1.5$

Internal Pressure Co-efficient are taken from Clause 6.2.3.2, Assuming less than 5% openings

Design Wind Force on Purlin Section = $(Cpe + Cpi) \times Pz \times c/c$ Distance Between the Purlins

6. Case Study:

In this paper the main emphasis is given on the utilization of CFSS as a structural member for purlins. Advantages of cold-formed steel section has been studied and discussed in this paper as an alternative to hot rolled section.

- Details of Sample Case 1: The problem is studied for 5m span of purlin with and without sag rod for roof slope of 10 degrees. The design is carried out by using Hot Rolled Steel Section with IS800:1984 and Revised IS800:2007. Similarly purlin member is designed by using Cold Formed Steel Section with IS801:1975.

Based on literature review and past experience, it is found that for Purlin design wind loads are predominant along with dead and live load combination. In view of the above fact, in this paper more attention is given on wind load and all the wind zones have been considered for purlin design. Results have been studied and compared for all the wind zones i.e. wind zone II to Wind zone VI.

All the purlin members have been designed for dead, live and wind loads for all possible worst load combination for strength and serviceability criteria by using well validated excel programmes. The compared results are well within permissible strength and serviceability limits. The most optimized section for different wind zones with weight comparison is also presented as shown in Figure 2 for case 1.
The effect on economy aspects for the purlin section designed by using IS800:1984 and compared with revised IS800:2007. Similarly, percentage saving in the cost due to utilization of cold formed sections (CFS) over hot rolled sections (HRS) designed by revised IS800:2007 is studied and discussed here:

1. For 5M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone V.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 37% for wind zone II & IV and 50% saving for wind zone V & VI.

2. For 5M span of purlin (with one sag rod)
   - The cost reduction in the purlin design by revised IS800:2007 due to use of one sag rod is around 22% for wind zone V.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 37% for zone II & V and 50% saving for wind zone VI.

3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 22% cost saving for zone IV & V.
   - Design by CFS: No effect on purlin design using sag rod for cold formed sections for this case. Hence additional cost saving can be achieved by without using sag rods in CFS.

- **Case 2:** Span of purlin 6m with and without sag rod for roof slope of 10 degrees.
  The most optimized section for different wind zones with weight comparison is presented as shown in Figure 3.

![Figure 2](image_url)  
**Figure 2:** wind zones Vs weight comparison for 5m span & 10° roof slopes.

![Figure 3](image_url)  
**Figure 3:** wind zones Vs weight comparison for 6m span & 10° roof slopes.
For Case 2, the following observations are made:

1. For 6M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 13% over design by IS800:1984 for wind zone V and V.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 43% for wind zones II to IV, 51% for wind zone V and 48% saving for wind zone VI.

2. For 6M span of purlin (with one sag rod)
   - The cost reduction in the purlin design by revised IS800:2007 due to use of one sag rod is around 14% for wind zone V & VI.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 43% for zone II to V and 51% saving for wind zone VI.

3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - Around 14% cost saving for zone VI.
   - Design by IS800:2007 – Around 14% cost saving for zone V & VI.
   - Design by CFS: Around 18% cost saving for zone VI.

![Figure 4: wind zones Vs weight comparison for 8m span & 10° roof slopes.](image)

Case 3: Span of purlin 8m with and without sag rod for roof slope of 10 degrees.
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 4

For Case 3, the following observations are made:

1. For 8M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 13% over design by IS800:1984 for wind zone II, 37% for zone III, 27% for IV, 15% for zone V and 28% for wind zone VI.

2. For 8M span of purlin (with one sag rod)
   - The cost reduction in the purlin design by revised IS800:2007 due to use of one sag rod is around 14% for wind zone II, 37% for wind zone III & 27% for wind zone IV to VI.

3. For 8M span of purlin (with two sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of two sag rods.

4. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - Around 14% cost saving for zone IV to VI.
   - Design by IS800:2007 – Around 13% cost saving for zone II, 37% for zone III and around 27% for zone IV to VI.

5. Percentage saving in material cost due to use of two sag rods:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 13% cost saving for zone IV and VI.
   - No suitable sections are available for above said case. The applications of Cold Formed sections are limited up to 7m span only, so no observations are drawn for CFS over HRS for span 8m for all the wind zones.
**Case 4**: Span of purlin 5m with and without sag rod for roof slope of 15 degrees. 
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 5

![Figure 5](image)

*Figure 5*: wind zones Vs weight comparison for 5m span & 15° roof slopes.

For Case 4, the following observations are made:
1. For 5M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone VI.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 43% for wind zones II to V and 55% saving for wind zone VI.
2. For 5M span of purlin (with one sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of one sag rods.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 43% for zone II to VI.
3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 22% cost saving for zone VI.
   - Design by CFS: No effect on purlin design using sag rod for cold formed sections for this case. Hence additional cost saving can be achieved by without using sag rods in CFS.

**Case 5**: Span of purlin 6m with and without sag rod for roof slope of 15 degrees. 
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 6

![Figure 6](image)

*Figure 6*: wind zones Vs weight comparison for 6m span & 15° roof slopes.
For Case 5, the following observations are made:
1. For 6M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone III and 14% for zone VI.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 15% for wind zones II, 35% for zone III to V and 44% saving for wind zone VI.
2. For 6M span of purlin (with one sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of one sag rods.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 16% for zone III to V and around 35% for zone IV to VI.
3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 22% cost saving for zone III and 14% for wind zone VI.
   - Design by CFS: No effect on purlin design using sag rod for cold formed sections for this case. Hence additional cost saving can be achieved by without using sag rods in CFS.

Case 6: Span of purlin 8m with and without sag rod for roof slope of 15 degrees.
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 7

![Figure 7: wind zones Vs weight comparison for 8m span & 15° roof slopes.](image)

For Case 6, the following observations are made:
1. For 8M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 14% over design by IS800:1984 for wind zone III to zone VI.
2. For 8M span of purlin (with one sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of one sag rods.
3. For 8M span of purlin (with two sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of two sag rods.
4. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - Around 14% cost saving for zone IV to VI.
   - Design by IS800:2007 – Around 14% cost saving for zone III, 26% for zone IV & V and around 27% for zone VI.
5. Percentage saving in material cost due to use of two sag rods:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 - No effect on purlin design
   - No suitable sections are available for above said case. The applications of Cold Formed sections are limited up to 7m span only, so no observations are drawn for CFS over HRS for span 8m for all the wind zones.
Case 7: Span of purlin 5m with and without sag rod for roof slope of 20 degrees.
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 8

Figure 8: wind zones Vs weight comparison for 5m span & 20° roof slopes.

For Case 7, the following observations are made:
1. For 5M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone VI.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 43% for wind zones II to V and 55% saving for wind zone VI.
2. For 5M span of purlin (with one sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of one sag rods.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 43% for zone II to VI.
3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 22% cost saving for zone VI.
   - Design by CFS: No effect on purlin design using sag rod for cold formed sections for this case. Hence additional cost saving can be achieved by using CFS.

Case 8: Span of purlin 6m with and without sag rod for roof slope of 20 degrees.
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 9

Figure 9: wind zones Vs weight comparison for 6m span & 20° roof slopes.
For Case 8, the following observations are made:

1. For 6M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone II to IV and 14% for zone VI.
   - The saving in cost due to utilization of Cold Formed Sections (CFS) over Hot Rolled Sections (HRS) is around 33% for wind zones II to V and 43% saving for wind zone VI.

2. For 6M span of purlin (with one sag rod)
   - The increase in cost due to design by revised IS800:2007 is 22% over design by IS800:1984 for wind zone II to IV.
   - The saving in cost due to use of Cold formed sections (CFS) over Hot rolled sections (HRS) is around 33% for zone II to VI.

3. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 – Around 14% cost saving for wind zone VI.
   - Design by CFS: No effect on purlin design using sag rod for cold formed sections for this case. Hence additional cost saving can be achieved by using CFS.

Case 9: Span of purlin 8m with and without sag rod for roof slope of 20 degrees.
The most optimized section for different wind zones with weight comparison is presented as shown in Figure 10.

Figure 10: wind zones Vs weight comparison for 8m span & 20° roof slopes.

For Case 9, the following observations are made:

1. For 8M span of purlin (without sag rod)
   - The increase in cost due to design by revised IS800:2007 over design by IS800:1984 is around 14% for wind zones III, 26% for zone IV, 14% for zone V & VI.

2. For 8M span of purlin (with one sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of one sag rods.

3. For 8M span of purlin (with two sag rod)
   - No effect in the purlin design by revised IS800:2007 over IS800:1984 due to use of two sag rods.

4. Percentage saving in material cost due to use of one sag rod:
   - Design by IS800:1984 - Around 14% cost saving for zone V & VI.
   - Design by IS800:2007 – Around 14% cost saving for zone III and around 27% for zone IV to VI.

5. Percentage saving in material cost due to use of two sag rods:
   - Design by IS800:1984 - No effect on purlin design.
   - Design by IS800:2007 - No effect on purlin design

★ No suitable sections are available for above said case. The applications of Cold Formed sections are limited up to 7m span only, so no observations are drawn for CFS over HRS for span 8m for all the wind zones.
7 Observations:
- Purlins designed without using sag rods by revised IS800:2007 is more conservation for higher wind zones as compared to design by IS800:1984.
- Cost saving can be achieved for purlins designed by using cold formed steel (CFS) for all the wind zones in all the cases as compared to hot rolled sections.
- In case of purlins designed by cold formed steel (CFS), for lower wind zones percentage cost saving is less whereas for higher wind zones percentage cost saving is higher as compare to hot rolled sections.
- No effect of sag rod was observed when purlins designed by IS800:1984, except for 6m & 8m span of purlin in higher wind zones.
- Cost saving can be achieved for purlins designed by revised IS800:2007 using sag rods for all the cases in higher wind zones.
- No effect on purlin design using sag rod for cold formed sections was observed for all the cases. Hence additional cost saving can be achieved by without using Sag rods in CFS.
- The above comparisons show that, high strength to weight ratio of Cold formed section helps in gaining almost in the range of 14 – 59 % economy in various cases.
- The advantage of cold formed sections (CFS) being lighter in the weight of steel results in economies in steel costs as compared with hot rolled sections.
- Due to the non availability of sections, the applications of Cold Formed sections are limited up to 7m span only. No observations are drawn for CFS over HRS for span 8m for all the wind zones and for different slopes.

8. Conclusion:
From the above study and observations it can be concluded that, the cold-formed steel sections (CFS) can suitability used as an replacement to hot rolled section for the lighter load bearing applications i.e. for purlins members.

It is very obvious that, thinner section will results in reducing the weight of steel. This reduced weight of steel will helps in reduction of steel costs as well as in the costs of handling, transportation and erection. Indeed, this will be one of the main reasons for the popularity and the consequent growth in the use of cold rolled steel. In fact, with the evolution of attractive coatings and the possibility in manufacturing of versatility in profile shape, cold formed steel (CFS) has been used for highly pleasing designs in construction industry. Even though the Cold Formed Sections are more economical compared with Hot Rolled sections, but due to the non availability of suitable sections the usage Cold Formed sections as purlin members are restricted up to 7m span only.

9. References
[6] Prof. S.R.Satish Kumar & Prof. A.R.Santha Kumar, “Design of Steel Structures”.