Economical Study on the Use of Hollow Steel Sections in Light Industrial Sheds

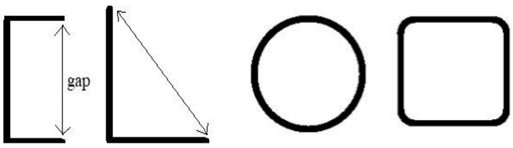
Subha Sinha, Shivangi Mishra, Shashank Saurabh, Rajan Kumar, Rahul Kumar

Abstract*: Hollow steel sections can withstand forces leading to high buckling, more effectively as compared to their open sections counterparts. The distribution of mass about the polar axis is more uniform in hollow sections as compared to open sections. This provides it a higher strength to weight ratio. Hollow sections have been proved more efficient as a truss and roof members. In present work, Hollow steel sections have been used in industrial shed building and compared with their open section counterpart. The scenarios of hollow sections are examined for change in height, change in bay length and change in span and the percentage cost savings and weight reduction are calculated. The study shows that the Hollow sections are more economical than the open section. However with increasing parameter, the economy shows a trend of shifting from hollow to open sections.

Keywords: Hollow Steel Sections, Industrial shed

I. INTRODUCTION

The structural sections having a hollow or tubular profile are generally called hollow sections. These sections are also called closed sections. This is because unlike open sections where there is an appreciable gap between the profile edges, there is minimum gap or no gap between the profile edges of a closed section.



Open sections closed section

Fig. 1 Open and Closed Sections

Design is an interactive process between the functional and architectural requirements and the strength and fabrication aspects. In a good design, all these aspects have to be considered in a balanced way. Due to the special features of hollow sections and their connections it is even here of more importance than for steel structures of open sections. Many examples in nature like bamboos and reeds etc. show the excellent properties of the tubular shape with regard to loading in compression, torsion and bending in all directions. These excellent properties are combined with an attractive shape for architectural applications. Furthermore, the closed shape without sharp corners reduces the area to be protected and extends the corrosion protection life. Another aspect which is especially favorable for circular hollow sections is the lower drag coefficients if exposed to wind or water forces. The internal void can be used in various ways, e.g. to increase the bearing resistance by filling with concrete or to provide fire protection. In addition, the heating or ventilation system sometimes makes use of the hollow section columns.

II. LITERATURE REVIEW

It was much after the industrial revolution when the hollow sections were manufactured by the steel industries. In 1886, the Mannesmann brothers developed the skew roll piercing process which made it possible to roll short thick-walled tubulars. This process, in combination with the Pilger Process developed some years later, made it possible to manufacture longer thinner walled seamless hollow sections.

An outstanding example of bridge design is the Firth of Forth Bridge in Scotland (1890) with a free span of 521 m. This bridge has been built up from tubular members made of rolled plates which have been riveted together because other fabrication methods were not available for these sizes at that time.

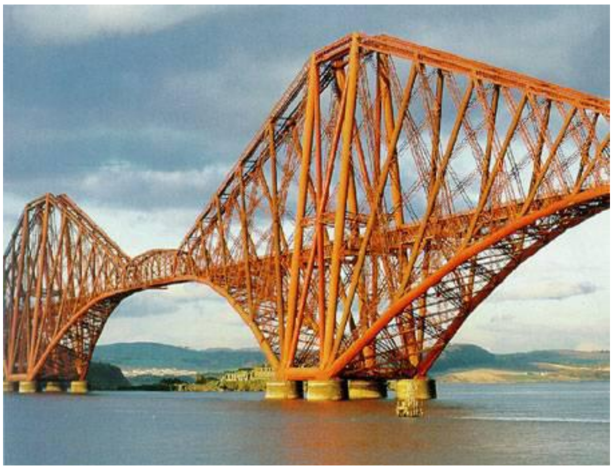


Fig 2. Firth of Forth Bridge in Scotland

Some other famous structures where hollow sections were used extensively are:-

Pavilion of Seville, Movable Bridge in Delft.

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Fig. 3 Pavilion of Seville Fig. 4 Movable Bridge in Delft

Nowadays hollow sections are conveniently used in bridges, buildings, barriers, industrial sheds, offshore structures, jacketing etc. In Bihar hollow sections are very common in the toll booth structures in the national highways.

Fig. 5 Examples of Hollow Steel Section

Earlier research works

J. Wardenier has contributed to a great extent in the analysis of hollow sections. This can be reflected in his work on HOLLOW SECTIONS IN STRUCTURAL APPLICATIONS, which is a book made available for free. The book covers all the mechanical and structural aspects of hollow sections. Extensive research has been done on the joints, their design and construction. A special emphasis has been to the analysis of concrete filled composite section.

Vaibhav B. Chavan, Vikas N. Nimbalkar, Abhishek P. Jaiswal. Their work aims to evaluate the economic significance of the Hollow Structural Sections (HSS) in contrast with open sections. This study was carried out to determine the percentage economy achieved using Hollow Structural Sections (HSS) so as to understand the importance of cost effectiveness. The technique used in order to achieve the objective included the comparison of different profiles for various combinations of height and material cross-section forgiven span and loading conditions. The analysis and design phase of the project was performed using STAAD PRO V8i. The sample results of STAAD analysis were validated with the results of Manual analysis.

Souvik Chakraborty, Amiya K. Samanta

The authors make an attempt to design a 800 capacity auditorium using both structural steel and steel tube and a detailed comparative study (both member wise and cost wise) has been presented in order to effectively utilize the both in design. Detail planning has been prepared. STAAD Pro V8I is used to analyse the truss whereas the other members are analysed manually using elastic method of analysis. The design is carried out using limit state method as per the latest Indian Standard code (IS: 800-2007) of practice and an estimation of quantity of steel required is made in order to have an idea about the cost of construction. An auditorium of 800 capacity having plan area of 36m x 30m located in Kolkata is considered for design. The plan has been prepared in detail to accommodate the seating capacity. It consists of one central and two side aisles each of width 1.5m. The 15m wide performing stage is provided 1.0 m above the aisles. The sideway Centre-to-Centre distance is 0.5m and row distance is 0.75. There are 6nos. column bays with longitudinal spacing equal to 7.2m. Calculation of consumption of steel and forces on all members of truss are done using STAAD PRO V8I. Tubular sections are proved to be economical around 20% of saving in cost is achieved.

M. G. KalyanshettiAnd G.S Mirajkar

In this case study of Sholapur, Maharashtra, modified How truss of span 24m, plan area around 800 sq. m, spacing of roof truss is 5m, No. of trusses are 8 is taken for design of industrial building. The sections are used both conventional and tubular sections. This study is focus to prove economy for choosing optimum steel section for given truss configuration. In this study all sections required for the different members of truss is compared between conventional and tubular sections. Closed hollow steel sections are the optimum replacements compare to the conventional steel sections owing to their better and useful properties. It is fact that because of profile of the hollow steel section, dead weight of the section is likely to be diminished for many structural members which emanates overall economy of the structure.

This study is related to the load carrying capacity of all structural members, economy and their safety measures respectively. Prime purpose of this study is comparison of closed hollow steel section with conventional steel section of given above requirements. This study proves that tubular sections are economical by saving of 40% to 50% in total cost is achieved.

III. METHODOLOGY

Present work aims to deal with the analysis of variation of parameters of structure such as cost, weight, change in percentage weight reduction and change in percentage cost saving due to change in height, bay length and span of structures. For the analysis, a typical industrial shed model is taken into consideration having four 'Pratt type' truss placed in constant distance.

For the purpose of analysis, the structure is designed by changing its height, bay length and span respectively with open section, square hollow section (SHS) and rectangular hollow section (RHS).

In our country, due to low demand in market and low manufacturing of hollow steel section its price in market is higher than open section for same weight of open steel section. To accommodate this 20% extra cost for hollow steel section with respect to open steel section has been considered as per market survey.

Load consideration

The load consideration for this analysis is given below: -

Dead Load: The Dead load of the structure is obtained from IS 875(Part 1)-1987. Load intensity due to sheeting and purlin at roof is taken as 30 kg/m2 and load intensity due to sheeting and runner on side element of structure is taken as 25 kg/m2.

Live Load: The imposed load on the roof is obtained from the Table 2 of IS 875 (Part 2)-1987. Also, the Dust load on roof is taken 50 kg/m2.

Wind load: For calculation of wind load, the IS 875(Part 3)-1987 is followed. All the structures analyzed in this project are assumed to be in Motihari city of Bihar. According to IS 875(Part 3)-1987, The basic wind speed, Vb is taken to be 47m/s. The design wind speed, Vz and pressure intensity, Pzfor different heights are calculated as per the related provision of IS.

Load combination considered are:

1.5 D.L
1.5 D.L +1.5 L.L
1.5 D.L +1.5 W.L(+xip)
1.5 D.L +1.5 W.L(+xis)
1.5 D.L +1.5 W.L(-xip)
1.5 D.L +1.5 W.L(-xis)
1.5 D.L +1.5 W.L(+zip)
1.5 D.L +1.5 W.L(+zis)
1.5 D.L +1.5 W.L(-zip)
1.5 D.L +1.5 W.L(-zis)
1.2 D.L + 1.2 L.L + 1.2 W.L(+xip)
1.2 D.L + 1.2 L.L + 1.2 W.L(+xis)
1.2 D.L + 1.2 L.L + 1.2 W.L(-xip)
1.2 D.L + 1.2 L.L + 1.2 W.L(-xis)
1.2 D.L + 1.2 L.L + 1.2 W.L(+zip)
1.2 D.L + 1.2 L.L + 1.2 W.L(+zis)
1.2 D.L + 1.2 L.L + 1.2 W.L(-zip)
1.2 D.L + 1.2 L.L + 1.2 W.L(-zis)

Modelling

For the purpose of analysis of project, project is classified in three different cases. All thecases are analysed with the help of STAAD.PRO.V8i software.

Case I: Variation of parameters of structures due to change in height:

For this analysis, we have taken three different structures having different heights. First structure having span of 6.8 m, bay length of 5 m and height of 6.7 m, has been designated as structure6.8x5x6.7.Similarly, second and third structure have same span and bay length but different heights of 10 m and 15 m, have been designated as structure 6.8x5x10 and structure6.8x5x15 respectively. Further, each structure is economically designed with open section, square hollow section and rectangular hollow section.

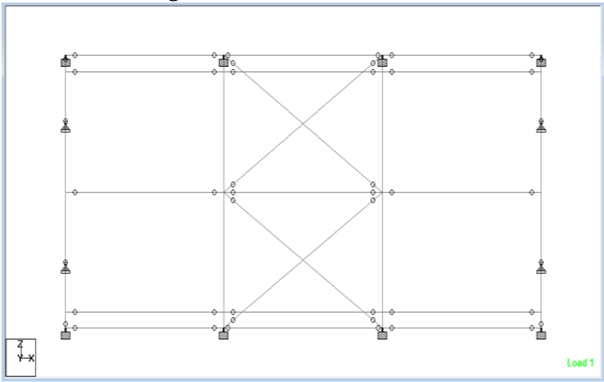

Figure 6:Typical plan of structures

Case II. Variation of parameters of structures due to change in Bay length:

For the analysis due to change in Bay length, we have taken three different structures. . First structure having span of 15 m, bay length of 5 m and height of 6.7 m, has been designated as structure15x5x6.7.

Similarly, second and third structure has same span and height but different Bay length of 10 m and 15 m, have been designated as structure 15x10x6.7 and structure 15x15x6.7 respectively. Further, each structure is economically designed with open section, square hollow section(SHS) and rectangular hollow section (RHS).

Case III. Variation of parameters of structure due to change in span:

For the analysis due to change in span, we have taken four different structures. First structure having span of 6.8 m, bay length of 5 m and height of 6.7 m, has been designated as structure6.8x5x6.7.

Similarly, second, third and fourth structure have same Bay length and height but different span of 9 m, 12 m and 15 m have been designated as structure 9x5x6.7, structure 12x5x6.7 and structure 15x5x6.7 respectively. Further, each structure is economically designed with open section, square hollow section(SHS) and rectangular hollow section(RHS).

IV. ANALYSIS AND RESULTS

Case I. Variation of parameters of structure due to change in height:

An in-depth analysis has been carried out for variation of weight of structure, cost of structure, change in percentage weight reduction and change in percentage cost reduction due to change in height. For this, three different heights have been taken for the structure (having height 6.7 m, 10 m and 15 m) and further economically designed with open section, square hollow section and rectangular hollow section.

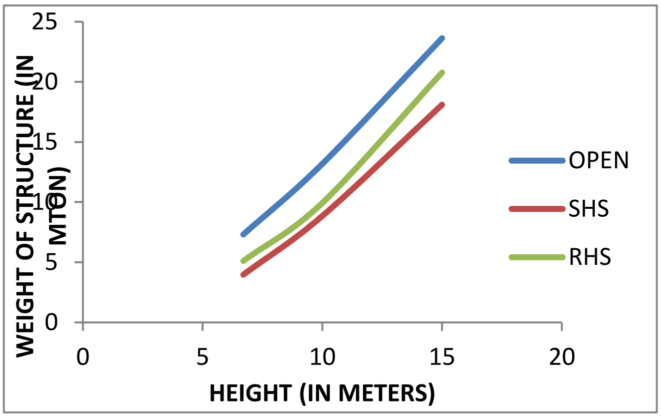

Figure 7 Variation of weight of structures due to change in height

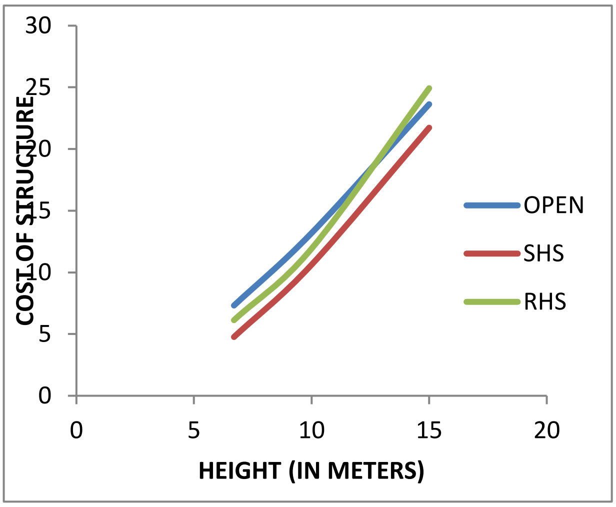

Figure 8Variation of cost of structures due to change in height

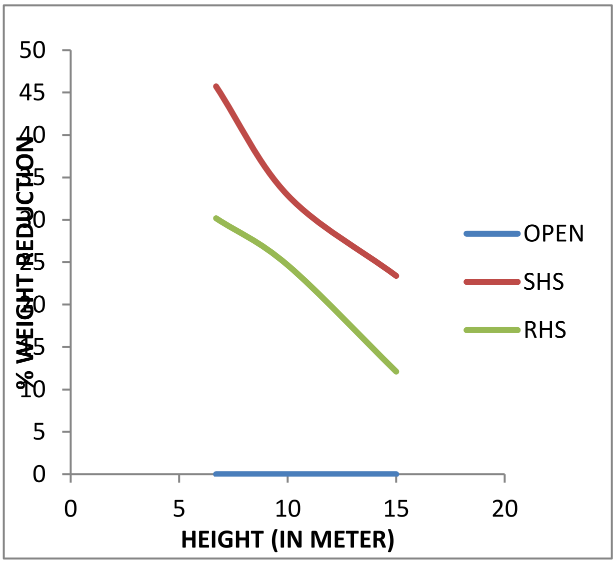

Figure 9Change in %weight reduction of structures due to change in height

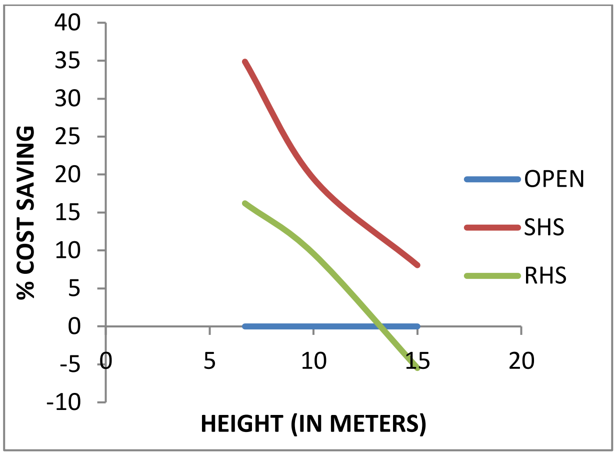

Figure 10Change in %cost saving of structures due to change in height

Case II. Variation of parameters of structure due to change in Bay length:

For this analysis, three different heightshave been taken of structure (having bay length 5m, 10m and 15m) and further economically designed with open section, square hollow section and rectangular hollow section.

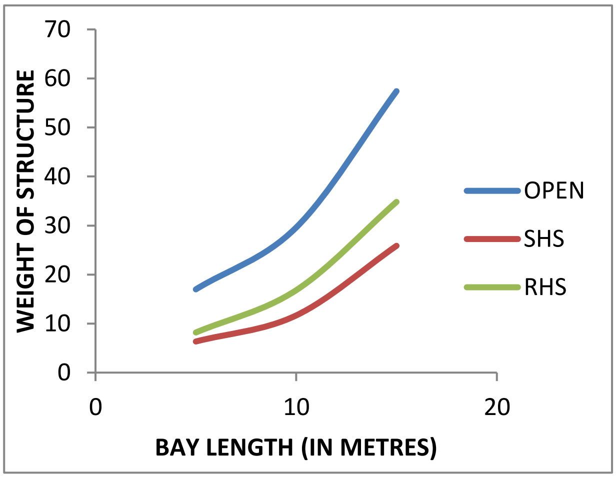

Figure 11variation of weight of structures due to change in bay length

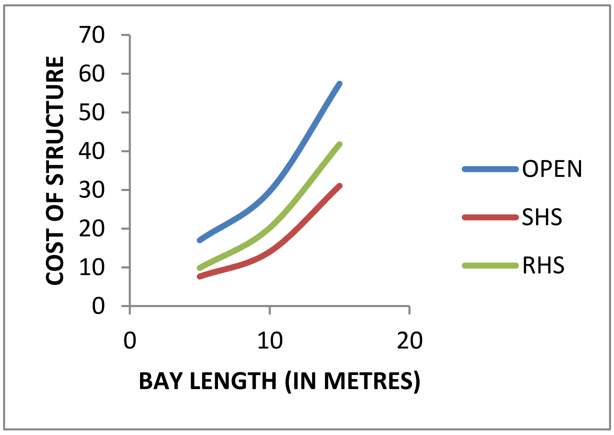

Figure 12variation of cost of structures due to change in bay length

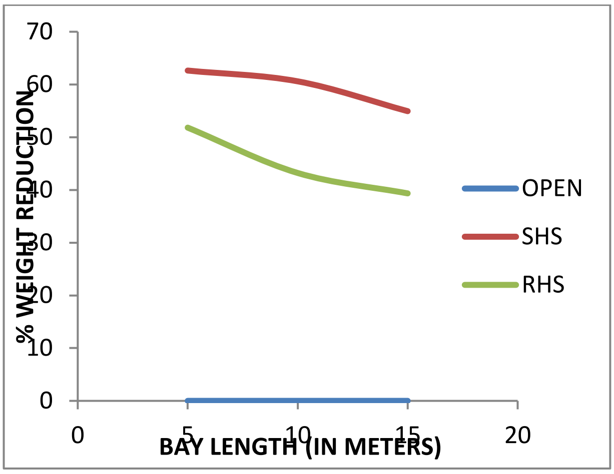

Figure 13change in %weight reduction of structures due to change in bay length

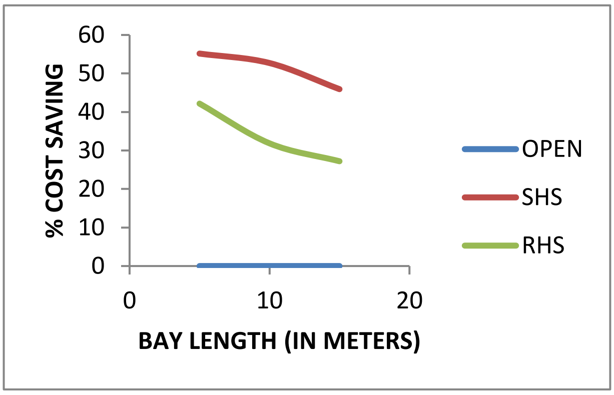

Figure 14change in %cost saving of structures due to change in bay length

Case III. Variation of parameters of structure due to change in span:

For this analysis, four different spans have been taken of structure (having span 6.8m, 9m, 12m and 15m) and further economically designed with open section, square hollow section and rectangular hollow section.

Table 3 Variation of parameters of structure due to change in span

From this analysis, it has also been found that the structure designed with SHS is economical and lighter for different length of spans. It has also been seen that in case of hollow section, change in percentage weight reduction and change in percentage cost saving first remain constant and then increase with the increase of length of span with respect to open sections.

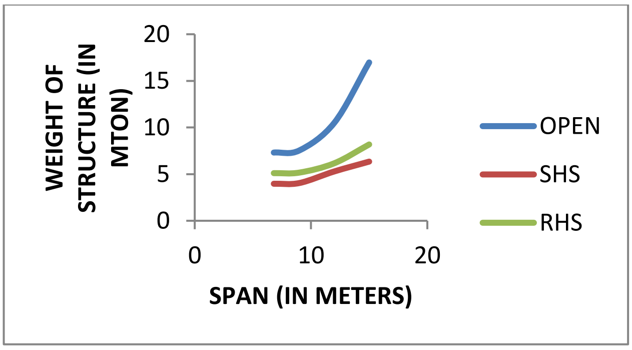

Figure 15. variation of weight of structures due to change in span

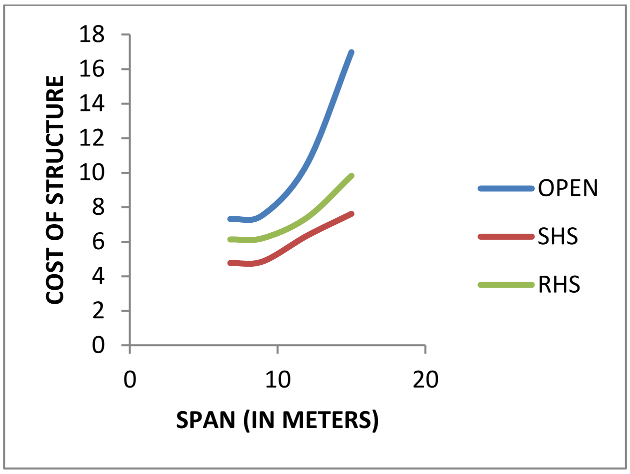

Figure 16variation of cost of structures due to change in span

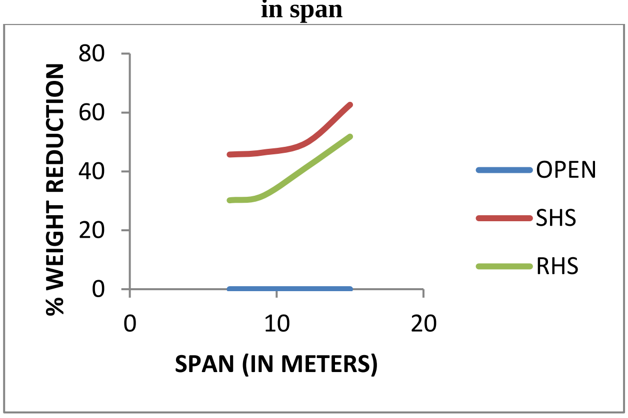

Figure 17change in %weight reduction of structures due to change in span

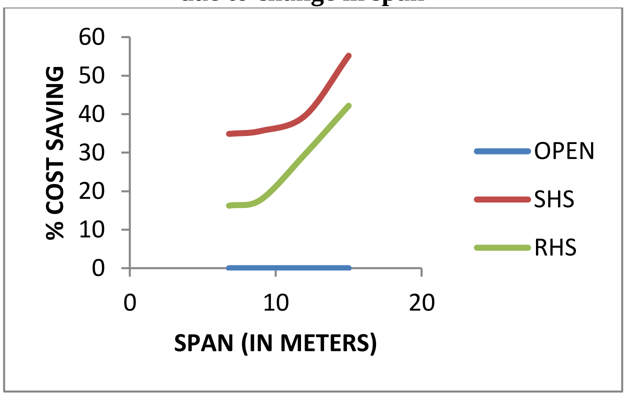

Figure 18 Change in %cost saving of structures due to change in span

V.CONCLUSION

1) It has been observed that as the height of the structure increases, the economy of the structure designed with hollow section decreases with respect to the open section. It has also been seen that the structure designed with RHS is more costly than open section after certain height. This is because for longer lengths there is a little difference between the strength of open sections and their comparative hollow sections when the cases of compression and bending acting together are considered.

Although hollow sections have greater strength but the cost gap between them outweighs the strength and economy tends to shift towards the open sections.

2) It is also observed that with the increase of bay length, economy of the structure increases in case of RHS as compared to that of SHS and open sections.The strength analysis of hollow sections and open sections has shown that in cases of uniaxial bending RHS are always better than SHS and open sections. This case is reflected in case of change in bay length of the structure where the increased bay length leads to increase in uniaxial bending of the members affected which, in this case are the side runners and the purlins.
3) It is also observed that economy of structure designed with hollow section increases with respect to open section with the increase in length of span.The increase of span leads to increase in the sizes of members of truss which in turn adds to the dead load on the columns. In cases of pure compression, open sections are better for smaller lengths and hollow sections are better for larger lengths. This is because as the length increases buckling effect comes into action. Also, with the increased span the cases of axial forces combined with biaxial and uniaxial bending are increased. In such cases hollow sections have greater than open sections.
4) It has been observed that the square hollow sections performed better than rectangular hollow sections except for the case where uniaxial bending was dominant. In all cases the use of SHS proved to be economical.
5) For the case of columns of larger lengths, the use of open sections in our case was economical as the bending was nominal.
6) In cases of truss members SHS is good choice when economy and strength is considered.

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