Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

Parametric Study of Framed Truss Systems forLarge Span Industrial Structures

Kamlesh Parihar

Associate Professor, Department of Civil Engineering, JIET. College, RTU, Jodhpur, (Raj)

Abstract:-*Use of high strength steel (300-350MPa) framed trusssystems is increasing in the current scenario instead of conventional mild steel (250 MPa) truss systems as it is structurally more efficient and has less depth requirement. Also due to development of good and efficient connection technologies,large industrialroofing systems are now using closed form tubular sections instead of traditional angles, channels and I-sections. The roof slope of the framed truss is kept in the range of 5^o-7^o as against 10^o-15^o for conventional trusses thereby reducing the exposed area for wind loads. As a result of above factors, framed trusses proves economical as compared to conventional trusses. But on the other hand use of lighter sections, results in increased deflection which needs attention. Lack of sufficient guidelines in Indian design codes, needs investigation in design parameters of framed trusses. So to optimize the design of framed trusses, influence of design parameters such as truss depth at eave and at ridge level, roof angle and number of panels have been studied to assess their impact/influence on the ridge deflection and self-weight of truss. It is observed that increasing the truss depth at eave proves economical in controlling ridge deflection rather than increasing the sizes of member. The results are presented in graphical form.*

Keywords:- *Framed truss, ridge deflection, eave, roof angle,industrial roof truss.*

I. Introduction

Truss system are vector active structural system. Short and straight linear members are assembled with pin joints. The direction of forces is same as the direction of its members and the nature of force is simple tension and compression. In trusses moment is resisted by forming force couple between tension and compression chord. In simply supported structures, moment varies parabolically with spanand hence, long span simply supported trusses demand large depth in the mid span region to achieve large lever arm.Due to, thislarge depth of truss, more area is exposed for wind load and design becomes uneconomical.In recent years, framed truss with tubular members have provided practical and economical design solution for such problems in warehouses, storage sheds, various factory buildings and other civil/military purpose building, particularly in the span range between 30-60m. The name framed truss indicates that truss is connected with column/s at two vertically separated points i.e. at top chord level& bottom chord level by pin connection (Fig. 1). The truss-column connection shares the mid span moment and this results in requirement of small and uniform depth of truss. Both top & bottom chord of framed truss are sloping and due to this slope stability increases and deflection reduces. There are many advantages of a framed truss like, larger spans are possible, availability of more clear height within the framed structure as compared to conventional simply supported truss structure, less truss depth requirement for given span in comparison to simply supported trusses, lighter and economical construction, advantage of both gable frame and truss system etc.

The most common form of framed truss is pinned-base framed truss. These framed trusses forms the primary framing structure of a pre-engineered building (PEB) which is the main load carrying and supporting component of the building. In pre-engineered buildings, the framed trusses are usually formed by welding together steel tubular members of high strength to form the truss panels. These panels of suitable sizes are then field-assembled (with bolted or welded connection) to form the entire framed truss. Mostly the rafter and columns (framing elements) are tapered (varying in depth) according to the local loading effect. Tapered elements are generally used in steel framed truss to make the stress, evenly distributed among the members so that, steel consumption can be reduced.Hollow sections, have gained popularity over the recent years. These sections have high bending and torsional rigidity compared to their weight and are most suitable for compressed members. In addition the large amount of research has provided guidelines to design and ensure the safety of tubular members and their joints. A Large range of tubular profiles is commercially available which makes it possible to choose appropriate profile in a truss. Hence tubular section has been chosen in the design of truss.

II. Brief Literature Review

J. Marshall[1], studied torsional behavior of structural rectangular hollow sections (RHS). It presented a basis for determining displacements and stresses arising from the torsional moment. Jeffrey A. packer, Piter C. Birkemore and William J. Tucker[2], provided design aids and design procedure for hollow steel section (HSS) trusses. Zhi-ming Ye , Roger Kettle and Long-yuan Li[9] carried out an analytical study on a model for cold-formed purlin-sheeting systems subjected to wind uplift loading in which the restraint of the sheeting to the purlin was taken into account by using two springs representing the translational and rotational restraints. Design standards for hot-rolled steel has been developed by American Institute of Steel Construction (AISC) to help its practicing engineers. Guidelines for design of a steel building has been laid down by AISI, but there exists limited guidelines and methodology in Indian Codes for design of steel framed trusses. Hence, design process becomes difficult due to lack of guidelines and standards for analysis of framed truss with uniform and tapered shape.

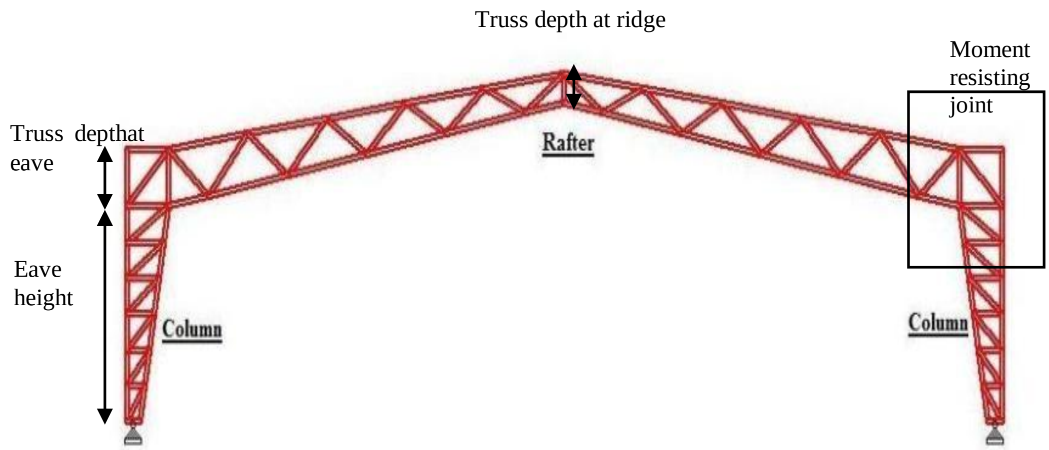


Fig. 1Typical framed truss

III. Parametric Study of Framed Truss

A parametric study of framed truss having trapezoidal configuration is carried out to observe the effect of key geometric parameters on the ridge deflection, and weight of truss. Such configuration are suitable and used for large span industrial buildings.The parameters under study are roof angle,truss depth at eave level and ridge level, shape of truss and no. of panels. The objective is to provide some guidelines to engineers in the primary selection of design parameters (as mentioned above) so as to arrive at an optimized and economical design. For this two framed trusses (Fig. 2) of 30 m span and 40 m span were chosen. The framed trusses were assumed to carry a uniformly distributed load of 10 kN/m. To economize the design, Hollow form rectangular sections were used confirming to IS 4923, "Hollow steel sections for structural use – Specification". Closed web sections have higher buckling and torsional strength as compared to open web section. The trapezoidal configuration makes the stress distribution uniform among members along the span and provides higher headroom in the central region. The design is carried out as per IS 800:1984, "Code of practice for general construction, in steel". High Strength Steel, with yield strength fy =310MPa, Unit mass, ρ = 7850 kg/m³, Modulus of elasticity, E = 2.0 x 10^5 N/mm² and Poisson ratio, μ = 0.3 is used in the study.

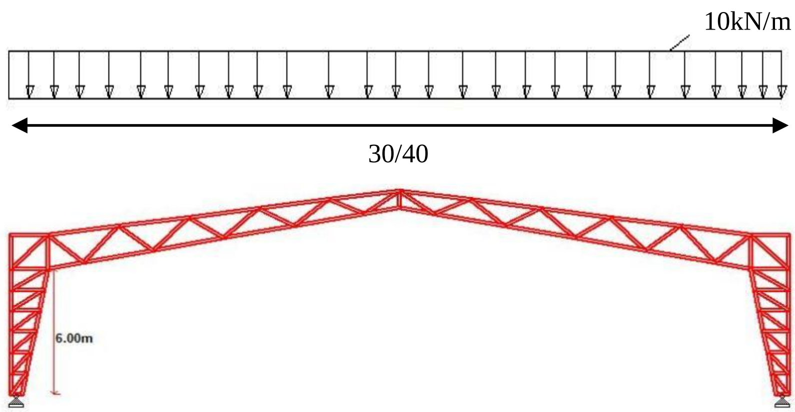


Fig. 2 Typical frame truss showing loading

Design parameters under study

3.1 Roof angle:
Roof angles considered for the study are 5º, 6º & 7º. This range of roof angles are taken under consideration for draining the storm water. For large spans, roof angles beyond 7° creates more height between eave and ridge level which is undesirable as it has more exposed area for wind.

3.2 Depth of truss at Eave& Ridge
No standard method or guidelines are available for deciding the depth of framed truss at ridge and eave level. It has been observed that with increase in depth of truss, better deflection control is achieved, but at the same time truss height and weight also increases. Based on the number of design trails, suitable range of truss depth at eave & ridge levelis decided for the study.These are tabulated below (Table 1)

3.3 Number of panel
Number of panels should usually be determined by reasonable choice of chord sizes, rather than by any formula. Desirable panel length is in the range of 1.5m to 3m. Based on this, no of panels has been varied between 12 to 20 for 30 m span truss and 20 to 28 for 40 m span truss.

Table 1. Details of parameters under study

Truss Geometric Parameters			
Span	**No. of Panels**	**Depth of truss at Eave (mm)**	**Depth at ridge (mm)**
30 m	12 to 20	1300, 1400 and 1500	600 to 1000
40 m	20 to 28	1500, 1600 and 1700	600 to 1000

3.4 STAAD. PRO Modeling
All the cases were analyzed and designed in STAAD. Pro 2007 software and results (deflection at the ridge, and weight of the truss frame) for each analysis are presented in graphical form to ease the understanding (Fig. 3).

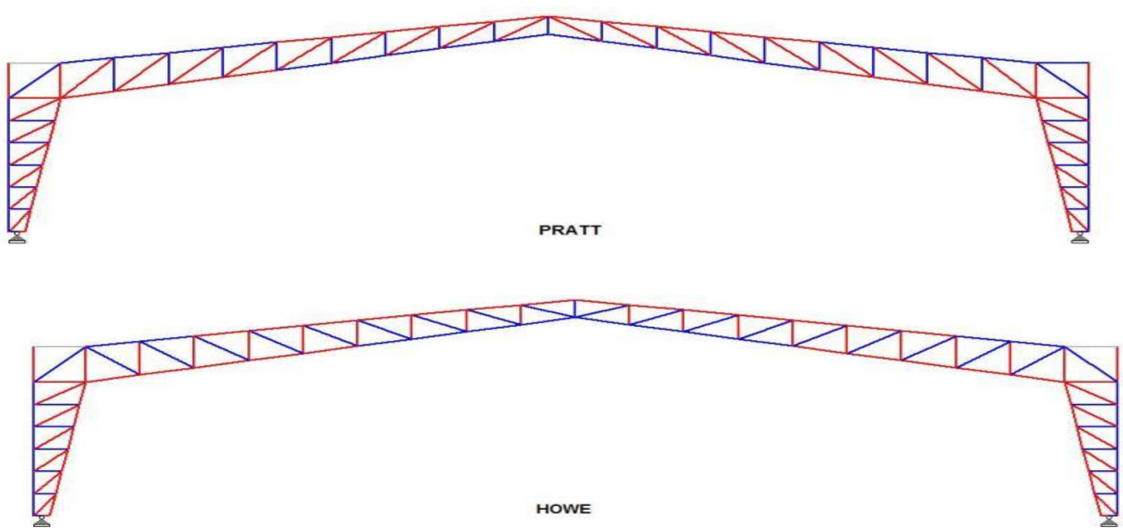


Fig. 3 Typical STAAD Pro model showing forces in truss members in different forms of trusses for gravity loading. Red color indicates members in compression whereas blue color indicate members in tension

IV. Results

4.1 Effect of truss depth at ridge and at eave on ridge deflection and trussweight

For 30 m span (case 1, case 2 and case 3)truss depth @ eave has been varied as 1300 mm, 1400 mm and 1500 mm. Roof angle has been varied between 5^{o} to 7^{o}. The results are presented below.

Case 1: Span = 30 m, roof angle = 5°, ridge height from eave level = 1.312m(Fig. 4)

D1 & W1 are the values of deflection & weight of truss frame with truss depth @ eave = 1300 mm
D2 & W2 are the values of deflection & weight of truss with frame truss depth @ eave = 1400 mm
D3 & W3 are the values of deflection & weight of truss with truss frame depth @ eave = 1500 mm

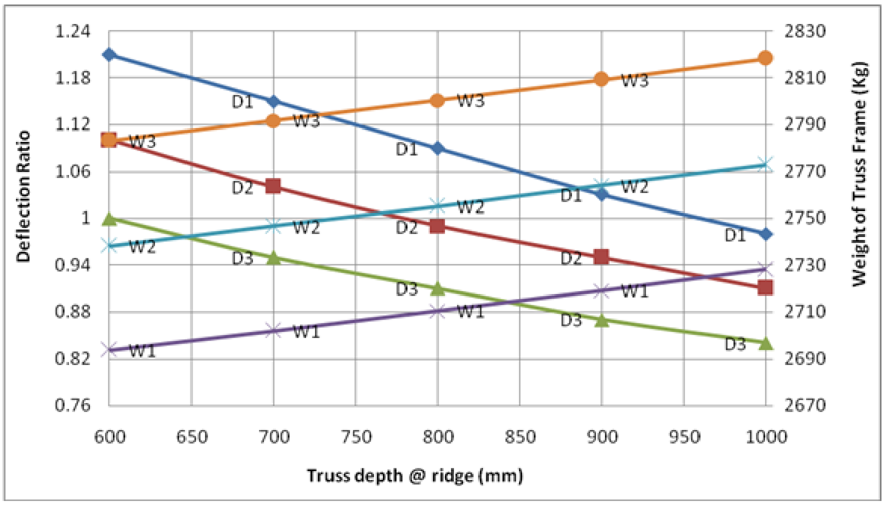


Fig. 4 Variation between (i) Truss depth @ ridge vs deflection ratio and (ii) Truss depth @ ridge vs weight of the truss

Observations

1) As the truss depth at eave increases from 1300mm to 1400mm and from 1400mm to 1500mm the percentage reduction in maximum deflection is 11% & 10%.
2) As the truss depth at eave increases from 1300 mm to 1400 mm and from 1400 mm to 1500 mm the percentage increase in the weight of the truss frame is 1.59 % & 1.77 % which is very small.

Case 2: Span = 30 m, roof angle = 6°, ridge height from eave level = 1.576 m(Fig. 5)

D1, D2, D3 & W1, W2, W3 are same as mentioned above for roof angle 5^{o}.

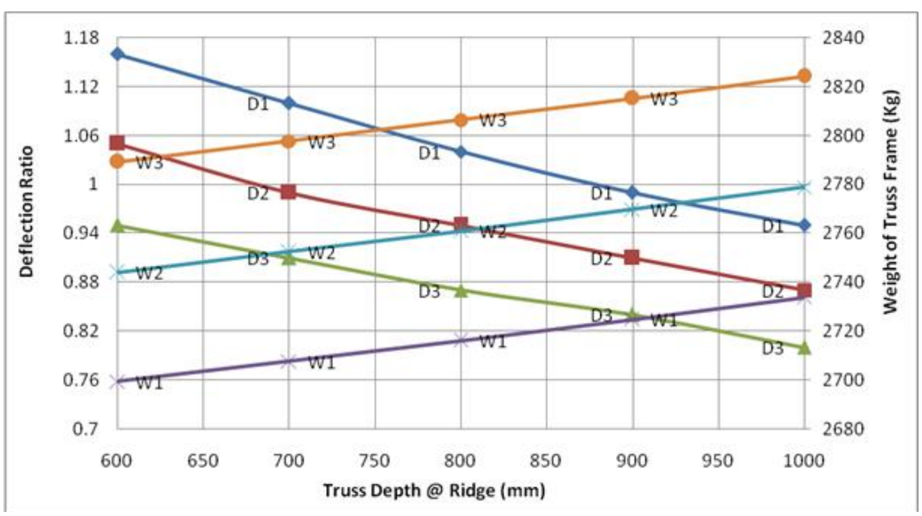


Fig. 5 Variation between (i) Truss depth @ ridge vs deflection ratio and (ii) Truss depth @ ridge vs weight of the truss

Observations

1) As the truss depth at eave increases from 1300 mm to 1400 mm and from 1400 mm to 1500 mm the percentage reduction in maximum deflection is 10.5 % & 10%.
2) As the truss depth at eave increases from 1300 mm to 1400 mm and from 1400 mm to 1500 mm the percentage increase in the weight of the truss frame is 1.58 % & 1.56 % which is again very small.

Case 3: Span = 30 m, roof angle = 7°, ridge height from eave level = 1.842 m(Fig. 6)

D1, D2, D3 & W1, W2, W3 are same as mentioned above for roof angle 5°.

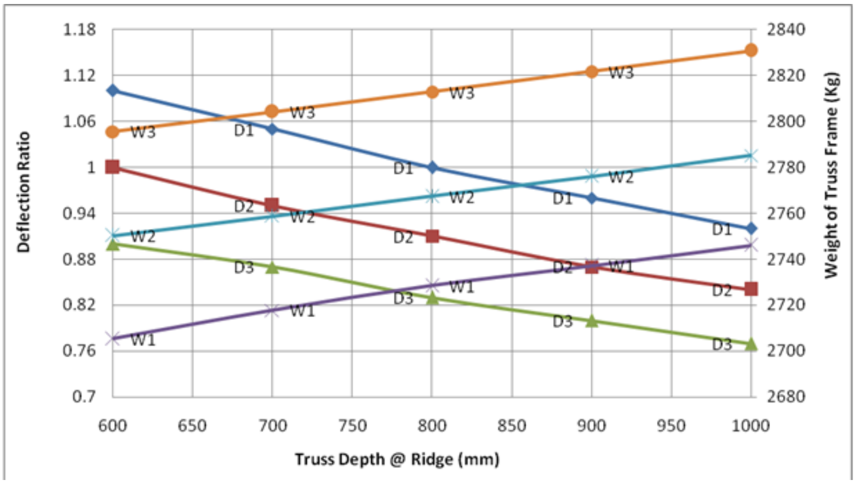


Fig. 6 Variation between (i) Truss depth @ ridge vs deflection ratio and (ii) Truss depth @ ridge vs weight of the truss

Observations

1) As the truss depth at eave increases from 1300 mm to 1400 mm and from 1400 mm to 1500 mm the percentage reduction in maximum deflection is 10% & 11 %.
2) As the truss depth at eave increases from 1300 mm to 1400 mm and from 1400 mm to 1500 mm the percentage increase in the weight of the truss frame is 1.32 % & 1.59 % which is again very small.

Similar results have been obtained for 40 span truss. Observations have been summarized below for brevity.

For 40 m span (case 4, case 5 and case 6) truss depth @ eave has been varied as 1500 mm, 1600 mm and 1700 mm

Case 4: Span = 40 m, roof angle = 5°, ridge height from eave level = 1.75 m

Observations

1) As the truss depth at eave increases from 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage reduction in maximum deflection is 9.5% & 8.2 %.
2) As the truss depth at eave increases from 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage increase in the weight of the truss frame is 1.76 % & 1.62 % which is very small.

Case 5: Span = 40 m, roof angle = 6°, ridge height from eave level = 2.1 m

Observations

1) As the truss depth at eave increases from 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage reduction in maximum deflection is 9.5% & 8.5 %.
2) As the truss depth at eave increases from 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage increase in the weight of the truss frame is 1.59% & 1.51 % which is again very small.

Case 6: Span = 40 m, roof angle = 7°, ridge height from eave level = 2.46 m

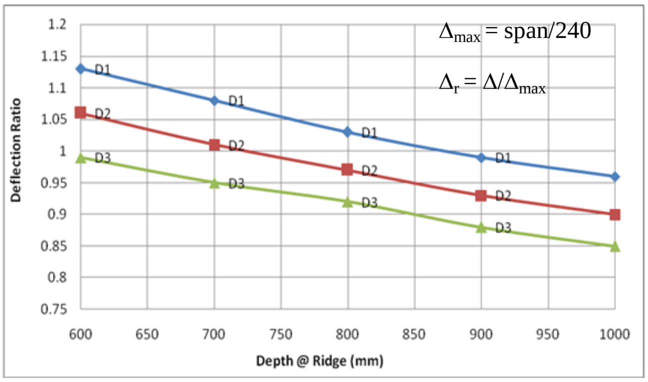
Observations

1) As the truss depth at eave increases from 1300 mm to 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage reduction in maximum deflection is 9% & 8 %.
2) As the truss depth at eave increases from 1500 mm to 1600 mm and from 1600 mm to 1700 mm the percentage increase in the weight of the truss frame is 1.36 % & 1.45 % which is again very small.

4.2 Effect of roof angle on deflection

Results of ridge deflection(Fig. 7 and Fig. 8) are also plotted against truss depth @ ridge for different roof angles to assess its effect. It can be easily observed that as the roof angle increases, deflection reduces. Also at higher truss depth @ ridge

deflection control is less. Reduction in deflection is in range of 12 to 13 percent for 30 m span and 8 to 9 percent for 40 m span. It also suggests that roof angle has more effect in reducing deflection on large spans.
D1, D2 and D3 are the values of deflection ratio for roof angle 5^o, 6^o and 7^o respectively



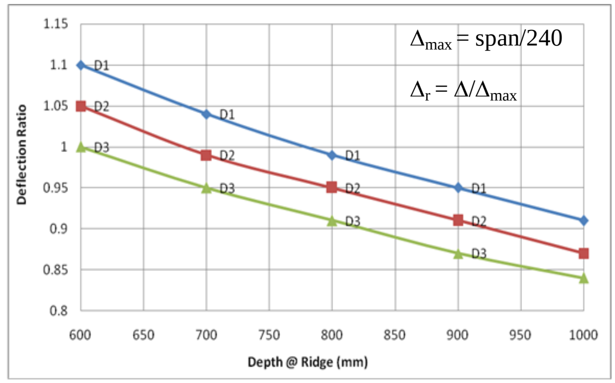
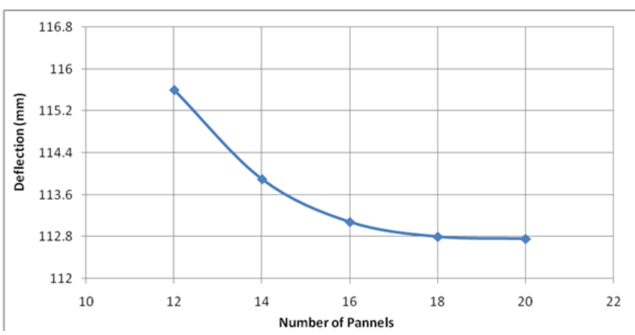


Fig. 7Depth @ ridge vs deflection ratio for various roof angles (span = 30 m and web depth @ eave =1400mm)
Fig. 8Depth @ ridge vs deflection ratio for various roof angles (span = 40 m and web depth @ eave =1500mm)

4.3 Effect of no. of panels on deflection

A Pilot study was also carried out in Pratt and How trussto assess the effect of no. of panels on deflection. Study was carried out for both 30 m and 40 span for roof angle 6^o .Results of 40 m span were very similar to 30 m span which are presented here(Fig. 9 and Fig. 10).It is observed that as the no.of panels increase, deflection reduces but the reduction is not significant. Also after a certain no. of panels, deflection control is not much affected by it.



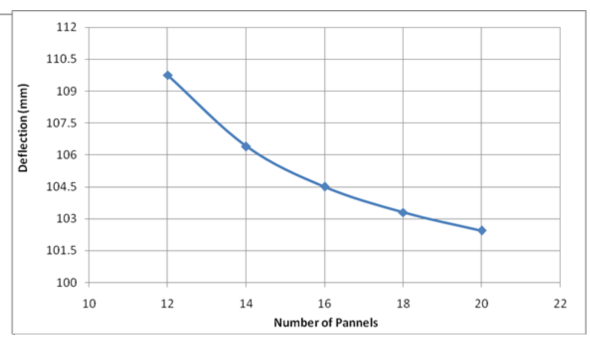


Fig. 9 Number of panels vs deflection for Pratt truss(span = 30 m and truss depth @ eave =1400mm, truss depth @ ridge = 700 mm)
Fig. 10 Number of panels vs deflection for Howe truss (span = 30 m and truss depth @ eave =1400mm, truss depth @ ridge = 700 mm)

V. Conclusions

Following conclusions can be made on the basis of above study:-

1) The performance of the framed truss in terms of deflection improves by 8-12 percent with increase in truss depth at eave level by 200 mm(1300 mm to 1500 mm or 1500 mm to 1700 mm) whereas the increase in the weight of truss is less than 1.8 %. Hence it is economical to increase the truss depth at eave level in order to satisfy deflection criteria instead of increasing the size of members.
2) Increasing the truss depth at ridge level also reduces the deflection, but it increases the overall depth and hence area exposed to wind. This in turn results in increased wind forces inmembers. It also reduces available headroom.
3) With an increase in roof angle from 5^o to 7^o, deflection reduces in the range of 8 to 13 percent. Roof angles above 7^o should not be preferred as it presents the same problem as explained above.
4) Increasingno. of panels reduce the deflection, but the effect is not significant. After a certain no. of panel, deflection control becomes negligible.

References

[1] J.Marshall, ARCST, B.Sc., MICE-Lecturer in Structural Engineering, University of Strathclyde, Glasgow, “Torsional Behaviour of Structural Rectangular Hollow Section”. Book of UDC 539.414, Page No/ 375-399.
[2] Jeffrey A. Packer, Piter C. Birkemore and J. Tucker, “Design Aids and Design Procedure for HSS Truss”.
[3] Wei-Wen Yu, Ph.D., “Cylindrical Tubular Members” Books of Cold Form Steel Structures Design, Analysis and Construction. Chapter-7, Page No. 276-291.
[4] J. Wardenler; Book on Hollow sections In Structural Applications.
[5] CEDECT; “Construction with Hollow Steel Sections – 3”, Design Guide for the Rectangular Hollow Section (RHS) Joints under Predominantly Static Loading.
[6] Jussi Jalkanen; “Tubular Truss Optimization Using Heuristic Algorithms”.
[7] Hancock G. “The Behavior And Design Of Cold-Formed Purlins”, Steel Construct 1997;15(3):2–16.
[8] Zhi ming Ye , Roger Kettle and Long-yuan Li, “Analysis of Cold-Formed Zed-Purlins Partially Restrained by Steel Sheeting”, Computers and Structures 82 (2004) 731–739.
[9] Ghosn A, Sinno R. “Governing Stresses in Z-Purlin Lap Joints. Journal of Structural Engineering” 1995;121(12):1735–41.
[10] Ho HC, Chung KF. “Experimental Investigation into the Structural Behavior of Lapped Connections Between Cold-Formed Steel Z Sections”, Thin-Walled Structures 2004;42(7):1013–33.
[11] Ho HC, Chung KF. “Analytical Prediction on Deformation Characteristics of Lapped Connections Between Cold-Formed Steel Z Sections”, Thin-Walled Structures 2006;44(1):115–30.
[12] Zhang L, Tong G, “Moment Resistance and Flexural Rigidity of Lapped Connections in Multi-Span Cold-Formed Z Purlin Systems”, Thin-Walled Structures 2008; 46(5):551–60.
[13] American Iron and Steel Institute (AISI), “Specification for the Design of Cold-Formed Steel Structural Members”; Washington, 1996.
[14] IS:800-1984, “Indian Standard General Construction in Steel-Code of Practice”
[15] BS5950:Part 5:1987—British standards – Structural use of steel work inbuildings, Part 5: “Code of Practice for Design of Cold-Formed Sections”.
[16] IS: 811:1987- “Indian Standard-Specifications for Cold-Formed Light Gauge Structural Steel Sections”
[17] IS: 806 – 1968-“Code of Practice for use of Steel Tubes in General Building Construction (First Revision)”, Bureau of Indian Standards.
[18] IS: 4923-1997, “Hollow Steel Sections for Structural Use-Specification”, BIS.
[19] IS: 875-1987, “Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures”:Part I to V.
[20] SP: 6(5) – 1980, “Hand Book for Structural Engineers: Cold Formed Light Gauge Steel structures”.
[21] SP: 38(S&T)-1987: “Handbook of Typified Designs for Structures with Steel Roof Trusses”
[22] Standards Australia/Standards New Zealand,“Cold-formed Steel Structures”, AS/NZS 4600; 1996”.
[23] EN-1993-1-1 : Euorocode 3: “Design of Steel Structures General Rules and Rules for Buildings”.
[24] “Design of Steel Structures” ---K.S.Sai Ram.
[25] S.K.Duggal (2000), “Design of Steel Structures”, 2nd edition, Tata Mc Graw Hill publishing company limited, Delhi.
[26] P.Dayaratnam (2003), “Design of Steel Structures”, 2nd edition, S.Chandpublication, Delhi.
[27] “Design of Steel Structures”, Bersler & Lin
[28] “Design of Steel Structures”,Subramanian. N.
[29] http://www.structural-engineering.fsnet.co.uk/free.htm (lists a number of free structural software packages).

