Interaction between saw-tooth roof truss and latticed girder for minimum weight proportions

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Interaction Between Saw-Tooth Roof Truss and Latticed Girder for Minimum Weight Proportions

Interaction entre poutre maitresse de toiture de forme dentellée et porteurs en treillis, compte tenu d'un rapport de poids minimum

Wechselwirkung zwischen sägezahnförmigen Dachbindern und Gitterträgern bei minimalen Gewichtsverhältnissen

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1. Introduction

Structural steelwork for the roof system for any industrial shed or heavy work-shop, needs careful design consideration. Usually saw-tooth roof system is adopted to take the advantage of the natural north light available throughout the day. In structural design of this system, choice of basic configuration and proportions for structural elements like saw-tooth truss and latticed girder is, by and large made arbitrarily by structural engineers based on certain thumbrules and their intuition gained from experience. Such an arbitrary choice increases the weight of structural steelwork.

Structural steel is very costly material and in many developing countries it is in short supply. Economy in context of the basic structural units having large number of repetitions is therefore a governing selection criterion.

The authors here have considered several geometrical and topological configurations to arrive at minimum weight proportions by making systematic use of interacting behaviour of weight of saw-tooth truss and supporting latticed girder.

Design variables, constraints and assumptions have been listed for clarity. Influence on weight of structural steelwork per unit area; for both, saw-tooth truss and supporting latticed girder is studied. Combined effect determines the proportions for minimum weight per unit area. Influence on economy is illustrated by considering a typical example. This shows an overall saving to be 40 to 50 per cent over arbitrarily selected and conventionally designed saw-tooth roof system.

2. Design Variables

In Fig. 1 are listed various design variables considered in

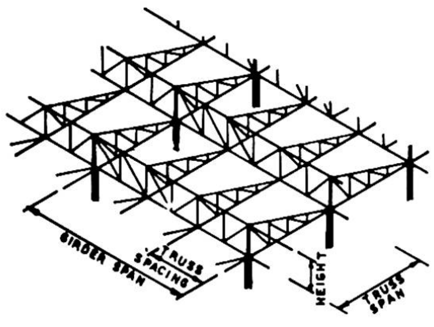

Fig. 1

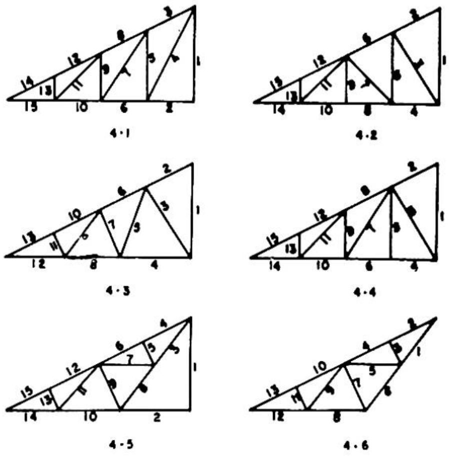

Fig. 2

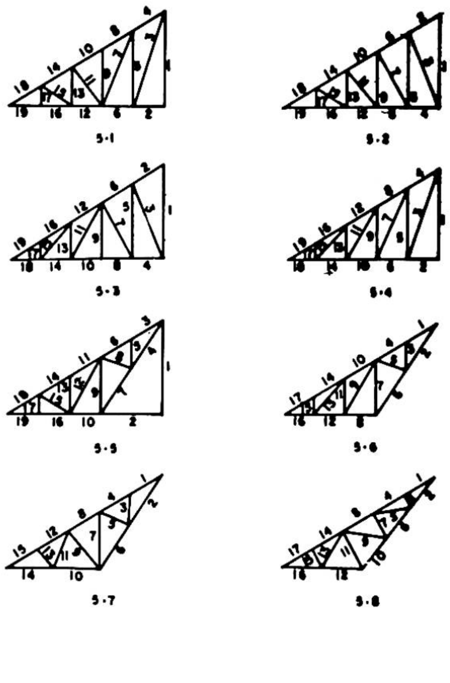

Fig. 3

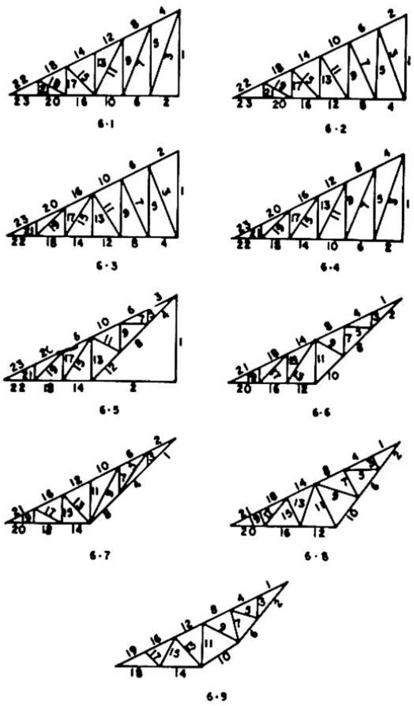

Fig. 4

the process to obtain minimum weight proportions. Number of panels in saw-tooth truss and in latticed girder are in addition to these. Only statically determinate configurations are considered.

3. Design Constraints

Minimum thickness of 6 mm for every section (1) is provided for weather resistance. Continuous members have the same cross-section, even though the forces in each of them differ.

Slenderness ratio is computed for least radius of gyration. The upper limits on slenderness ratio are 180 and 350 for compression and tension members, respectively (1). Effective lengths of continuous and individual compression members using welded connections, are taken as 0.70 and 0.85 times the member lengths, respectively (1). Permissible stresses in axial compression have been taken as specified in IS : 800-1962 (1). To account for reduced axial stress in outstanding leg of tension member, effective area is suitably derived (1).

Use of available single equal angle sections (2) is made for all members, except for the chords of latticed girders, which have two equal angle sections.

4. Design Assumptions

Following valid assumptions are made to simplify the design process, yet the structures designed are practicable and real ones.

1. Total uniformly distributed design load all inclusive of self-weight, sheeting weight and live load, on plan area is taken as 75 Kg/m^2 for all topological and geometrical configurations (3).

2. Only single loading condition with the design load mentioned above is considered. For the major portion of India stress reversals will not occur in general, with low degree of slope of saw-tooth truss (3). In particular cases, the effect of stress reversal will be very small and can be therefore neglected.

3. Bending of principal rafters of saw-tooth truss is neglected. Panel length is approximately fixed up considering maximum span which asbestos cement corrugated sheets, extensively used in India; can withstand without being overstressed or excessively deflected.

4. All joints are considered as hinged, though they are welded. Secondary stresses are neglected.

5. Influence on Weight of Saw-tooth Truss

Fig. 2 to 4 show various topological configurations considered for four, five and six panels, respectively.

From the direct search from various design solutions generated on CDC 3600-160A computer following inferences have been drawn by the authors.

With the increase in truss span, the weight increased. Larger truss spacings reduced the weight. These are quite obvious. Keeping even number of panels, increase in number of panels increased the weight. Odd number of panels appeared to increase the weight as compared to trusses with even number of panels. The optimum ratio of saw-tooth truss height to its span for minimum weight is observed to be 0.25.

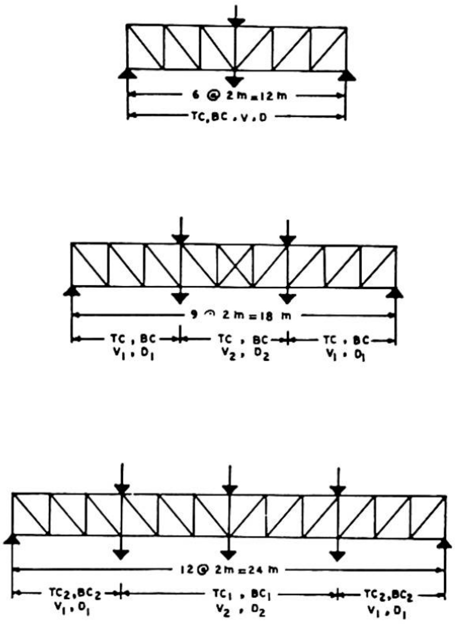

Fig. 5

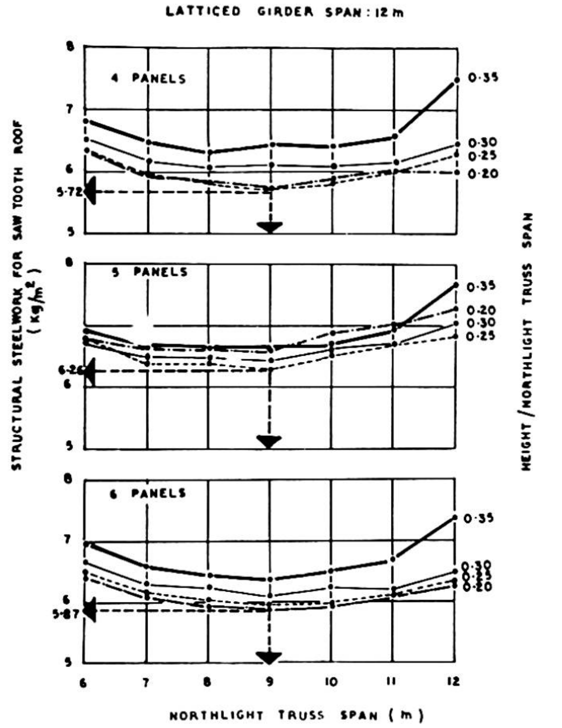

Fig. 6

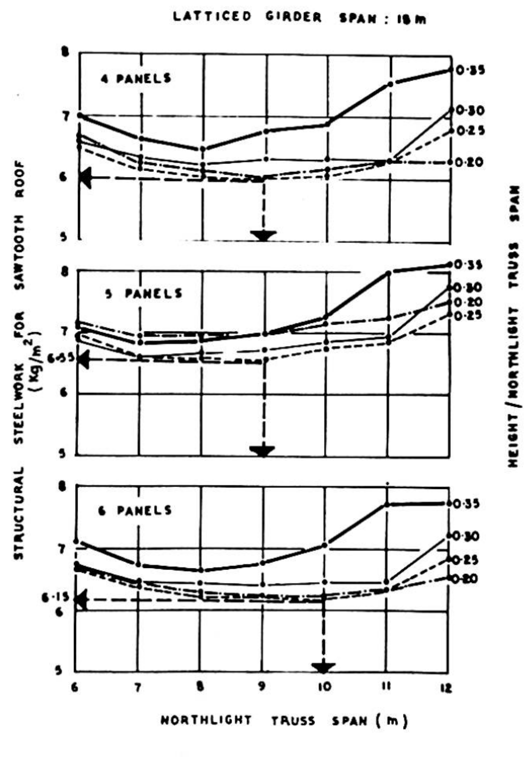

Fig. 7

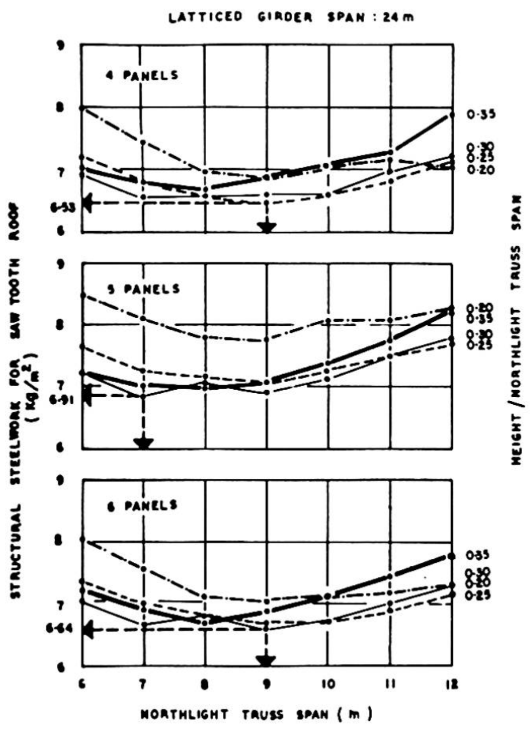

Fig. 8

Out of many topological configurations 4. 6, 5. 8 and 6.8 are found to give the minimum weight. Truss spacing should be large which can be easily accomplished using trussed purlin and a limit in this context has been drawn to 6 m. So, for further optimization, these variables are knocked out.

6. Influence on Weight of Latticed Girder

Three spans (in multiple of 6 m) (Fig. 5) are considered as 12 m, 18 m and 24 m. This covers fairly large range of spans which are normally constructed in saw-tooth roof system. The number of panels, correspondingly are 6, 9 and 12. This assumption made is in concurrence of actual practice and the chord length of 2 m has proved to be economical. Topology is assumed to be N type. It is advantageous with respect to the design of web members. Long diagonals are in tension and short verticals are in compression. This is in confirmation with the findings of Maxwell-Michells' theorems (4) which conclude that to obtain practical and yet relatively minimum weight truss, attempt should be made to minimize the weight of its compression members by proper selection of topology. Variations in the height are made but the uniformity to the height of saw-tooth truss is maintained. Keeping other parameters constant increase in girder span obviously increased its weight.

7. Weight Interaction of Saw-tooth Truss and Latticed Girder

Using topological configurations 4.6, 5.8 and 6.8 for saw-tooth truss with truss spacing as 6 m, interacting behaviour of saw-tooth truss weight and latticed girder weight is studied. Fig. 6 shows such a study for weight of structural steelwork for saw-tooth truss and latticed girder per unit area, for the latticed girder span as 12 m. Fig. 7 and 8 show similar studies for latticed girder spans of 18 m and 24 m, respectively.

It is quite clear from Fig. 6 to 8, that the minimum weight proportions are achieved if the saw-tooth truss span is 9 m, with a height/truss span ratio as 0.25 and the number of panels are only 4. Similar solutions for 6 panels are little higher and comparable, but solutions for 5 panels are quite higher in weight per unit area. This stresses that if proper choice on geometrical and topological configuration, plan dimensions and number of panels is not made, it will increase the total weight enormously.

8. Example

Using the approach presented above for a typical industrial shed of 18 m X 40 m in plan, in Western India total structural steel for saw-tooth roof system excluding purlins and wind bracings, worked out as 10,000 Kg. It will be interesting to know that a survey of similar structures in the same part of India revealed consumption of steel in the range of 17,000 Kg. to 21,000 Kg.

9. Conclusions

Systematic approach presented here can be easily used and can replace the intuitions or thumb rules, in determining proportions, geometry and topology.

Here only equal angle sections are considered, but where prefabrication is possible on huge scale other efficient sections such as tubes, can be easily dealt with.

Influence on economy will be worth noting in case of structures having large number of repetitions.

10. Acknowledgements

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Summary

Various geometrical and topological configurations for saw-tooth truss and latticed girder are designed for practical design constraints such as availability of sections, limits on slenderness ratio and minimum thickness of section. Interaction between weights of saw-tooth truss and latticed girder is utilised in obtaining minimum weight proportions which are practicable. Influence on economy by a proper choice has been focussed.