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Cost Comparative Study On Steel Frame Folded Plate Roofing System Vs Conventional Truss Roofing System

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ABSTRACT
Due to ever-increasing of construction materials, it becomes the foremost duty of a civil engineer to design economical and durable structures. In this project an attempt has been made to compare the cost of two types of roofing systems viz. conventional truss roofing system and steel frame folded plate roofing system. The steel frame folded plate roofing system, though found to be economical, is not widely practiced in India due to lack of knowledge regarding its analysis and design. On contrary to it, the conventional truss roofing system still remains as the widely adopted method of roofing for different types of buildings due to the available literature on its analysis, design and construction. The analysis and design of conventional truss roofing system and folded plate roofing system have been carried out for various spans. The analysis is carried out in STAAD.Pro 2004, which is based on stiffness method. Load calculations and design done manually, based on IS:875-1987, IS:800-1984 & SP:38(1987)
KEYWORDS: Cost, Comparative Study, Steel Frame Folded Plate Roofing System, Conventional Truss Roofing System

I INTRODUCTION

Space structures offer the possibility of providing very large column free areas and they are quite popular all over the world. Space structures can be built up with sample, prefabricated units of standard size and shape. These units can be produced in the factory and assembled rapidly at site by semi-skilled labor. The small size of components simplifies the handling, transportation and erection. Space structures are very economical for constructions like industrial buildings, sports stadium, assembly rooms, swimming pools, exhibition halls, etc., where large column free areas are required. These space structures also give aesthetic appearance. Due to their great rigidity and stiffness, they canresist large concentrated or unsymmetrical loading. They offer great flexibility in layout and positioning of columns. Even in case of fire, latticed space frames retain a fair margin of safety. In this project an attempt has been made to ascertain the cost effectiveness of space structures over the conventional systems of roofing.

1.1 SCOPE AND OBJECTIVE OF THE WORK

1. To gain confidence in the analysis and design of steel frame folded plate-roofing system.
2. To provide detailed report of the analysis and design of conventional truss roofing system.
3. To provide detailed report of the analysis and design of steel frame folded plate-roofing system.
4. To estimate the cost of the above mentioned roofing systems.
5. To perform a comparative study on the costs of the above mentioned roofing systems for different spans.
6. To study the cost effectiveness of triangular purlin over that of channel purlin.

The analysis of the roofing systems is done using available software and the load calculation and design are done manually.

The analysis, design and estimation of conventional truss roofing system as well as steel frame folded plate roofing system are done for an area with length 30 m and breadth of varying spans from 12 m to 24 m at an increment of 4 m. The spacing of trusses, taken as 6 m, is kept constant for all the spans.

Procedure for the load calculation, design of truss members and purlins and estimation of cost for conventional truss roofing system and steel frame folded plate roofing system is shown in detail for 24 m span. The design results and the percentage reduction in weight for the rest of the spans is given in a consolidated manner. The cost involved in the above said roofing systems are plotted in a graph to study the comparison of cost.

II REVIEW OF LITERATURE

In this chapter a brief review of the literature pertaining to the scope of the work is presented. Many linear and non-linear methods have been proposed for the analysis of folded plate roofing system, of which, the simplest and widely used one is the Baer's method. Baer considered the frame folded plate as a frame consisting of two inclined trusses rating on two rows of posts at the sides of the building, each truss being supported by the other at the peak of the building. The reactions of the trusses are assumed to be absorbed by the ties across the end pairs of posts. He assumed that the joints are pin connected and analyzed the structure by taking the two trusses separately and resolving the forces in the direction of these trusses. He then analyzed them as simple plane trusses. Baer extended his analysis to multibay frames also and suggested that no interior columns are necessary. He has advocated that the same procedure can be adopted for multibay frames also. He also showed that this analysis could be performed on barrel vaults. Baer's method of analysis in which the interaction between the two separate trusses is neglected, has been accepted as a standard method for analyzing such structures.

Also, a detailed review was made on the thesis work titled 'Steel Frame Folded Plate Roofs: A viable alternative to steel trusses' by Dr.N.Subramanian (CE, Computer design consultants, Chennai).

In his thesis work he has solved about one hundred and twenty five cases of steel frame folded plates to study their elastic behavior. The conclusions made by him are as follows:

1. The Baer's approximate method predicts the axial forces in the members with sufficient accuracy. But the large values of bending moments present in most the members are neglected by the Baer's approximate method. Hence, in structures designed by Baer's method, a comparatively large factor of safety seems to have been taken into account for these bending moments and this naturally leads to heavier structures.
2. The laterals and edge trusses should be provided in order to reduce the heavy bending moments present in many members. The edge trusses also reduce the axial forces and deflections.
3. The intermediate, stiffening trusses are not efficient in reducing the bending moments and deflections.
4. An edge truss of about 0.4 times the rise is suggested to efficiently design these structures for axial forces only.
5. A spacing of rafter of about 2.5m to 3m gives the minimum weight for this type of structure.
6. A pitch equal to 1/4th bay width gives an efficient system.
7. A bracing system is suggested which will give uniform stress distribution and will result in "minimum weight".
8. The folded plate roof with laterals is suggested for multibay roofs also since the behavior of this frame sis similar to that of a single bay frame. Laterals at alternate rafter points provide an efficient structural system.
9. It is seen that the behavior of frame folded plate roofs is satisfactory when the edge trusses and laterals are provided in the edge bay of multibay roofs. Moreover, the elimination of edge trusses and laterals in the intermediate bays increases the headroom in the intermediate bays.
10. The lack of fit of laterals has very small effect on the load carrying capacity of these structures.
11. The practical considerations like the settlement of support and different boundary conditions affect only the members provided along the corners of the frame. The forces and bending moments are reduced considerably only when the frame is supported at all the rafter points. But, the values of axial forces present in the members of intermediate bays are not much affected.
12. It is seen that the suggested bracing system is efficient in resisting the wind loads also.
13. The secondary effects caused by the rigid suggest plates and misalignment of members has very little effect on the load carrying capacity of these structures.
14. The buckling analysis of these structures shows that the buckling does not occur in the elastic range of the material. Hence, these systems can be safely adopted for industrial roofs as well as roofs for very large column free areas.

III STEEL FRAME FOLDED PLATE ROOFING SYSTEM

Space structures offer the possibility of providing very large column free areas. There are various types of space systems and they can be subdivided into three main classes. Skeleton frame works, stressed skin systems and suspended structures. Folded plate structures belong to the stressed skin systems.

Steel Frame Folded Plates have the advantage of simplicity in erection and these have the additional advantage of quick drainage of water because of their slope. It consists essentially of two inclined trusses resting on the columns at the corners of the buildings, each truss being supported by the other at the peak of the building. The end reactions of the trusses are absorbed by the ties across the pairs of columns. Edge trusses similar to those of reinforced concrete cylindrical shells can also be added to increase the efficiency of these structures. The members of the frame folded plates with edge trusses and laterals are illustrated. From the constructional standpoint most of the members required in the folded plate system are used in the traditional roof as secondary bracing. This results in considerable savings due to both decreased material cost and simplified fabrication. The separate trusses which form the folded plate can be fabricated separately and connected at the site to form the required shape by bolting, riveting, welding or by any other patented connection. Hence, the mass production of such structures in the factory is possible and they do not require any special machinery for fabrication. Steel frame folded plates are largely used in roofs for factory buildings, warehouses, sports stadium, airport hangers and in other places where large column free areas are required. In the conventional design the wind bracings are to be provided, whereas the folded plate roof is stiff enough because of the space structure action. If the weight of wind bracings is also considered, the saving in weight of steel in frame folded plate works out to 32%.

Need for Research

Only very little information is available on steel frame folded plate roofs. Approximate methods, which disregard the interaction between the separate trusses, have been accepted as the standard methods for analyzing such structures. It is necessary therefore to undertake a comprehensive analytical and experimental investigation of various aspects of this problem. Even though many structures have been built around the world, no attempt has been made to exactly analyze and to study the effects of various parameters like the pitch, length, spacing of rafters, laterals, edge truss and different types of bracings on the behavior of steel frame folded plate roofs.

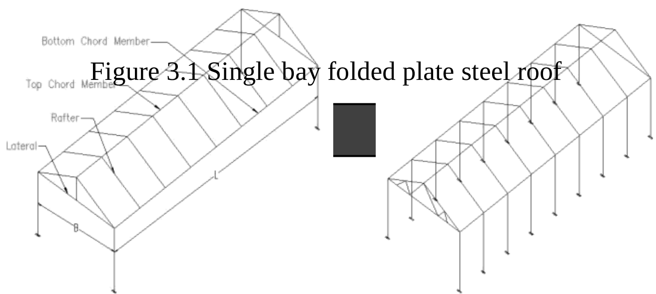
Analysis using Baer’s method

Baer’s approximate method has been accepted as a standard method for analyzing steel frame plate roofs. In this method the folded plate as shown in fig. 3.1 is assumed to consist of two inclined trusses resting on the two rows of columns at the sides of the building. It is also assumed that each truss is supported by the other at the peak of the building and that the end reactions at the trusses are absorbed by the ties across the end pairs of columns. The two trusses are assumed to support the entire roof loads by transverse bending in the sloping rafters. Since only pin connected joints are assumed, the bending moments in the members are neglected and also the interactions between the two separate trusses are not considered. The two inclined trusses are assumed to act together as an arched frame and that the springing reactions are absorbed by the end ties. The purlins are assumed to distribute the loads to the rafters and that they will not contribute to the structural action. Any vertical load that is applied to the rafter is assumed to be distributed proportionately to each end of the rafter, and carried tom the ground either directly by the post supporting the ends of the rafter or by the arch action of the inclined trusses transferring the applicable portion of the load to the four end post. It is also assumed that the end posts are provided to absorb the loads applied to the trusses in a direction non-coplanar to the planes of the trusses. Baer extends this method to multi-bay roofs and barrel shaped frames also and concluded no vertical supports are required under interior valleys. For designing a multi-bay roof, an intermediate truss is taken and the other are designed for the same force.

Limitations of Baer’s method

1. The redundant system being considered is commonly replaced by a statically determinate framework. In this process, the physical system rather than the mathematical models are relaxed.
2. If the joints are assumed to be pin connected, the system will not be stable. For the stable system of this type, the joints are to be rigid.

Figure 3.1 Single bay folded plate steel roof



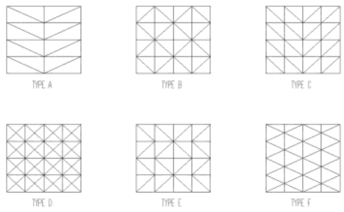


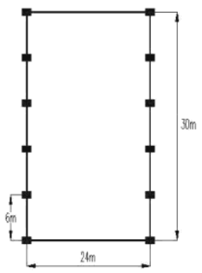
Figure 3.2 Different types of bracing system adopted in steel frame folded plate roofing.

IV CONVENTIONAL TRUSS ROOFING SYSTEM

Steel roof trusses are commonly used for industrial buildings, workshop buildings, storage godowns, warehouses and even for residential buildings, school buildings offices where the construction work is to be completed in a short duration of time. Temporary structures are invariably constructed with roof trusses of steel or timber. One of the greatest advantages of roof truss is that its mid span depth is the greatest – especially where B.M in the span is maximum, thus resulting in great economy. The sloping faces of roof trusses facilitate in easy drainage of water.

A roof truss is basically a framed structure formed by connecting various members at their ends to form a system of triangles, arranged in pre-decided pattern depending upon the span, type of loading and functional requirements. The joints are considered as pin joints where B.M is zero. External forces are applied at joints only (Compression member called struts; tension members called ties). In order to cover a certain area, trusses are placed along the shorter dimension, so that the span of the truss is least. To cover the entire area, trusses are placed parallel to each other and are supported on walls/columns suitably spaced along the long dimension. The inclined rafters of a truss are known as principal rafters. Purlins are supported on the principal rafters, thus spanning between the roof trusses. The roof coverings directly rest on purlins.

PLAN OF THE AREA



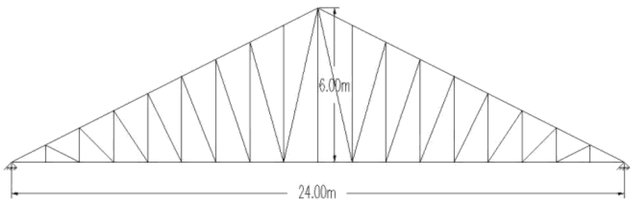


Figure4.1 Conventional truss roofing system for span of 4m.

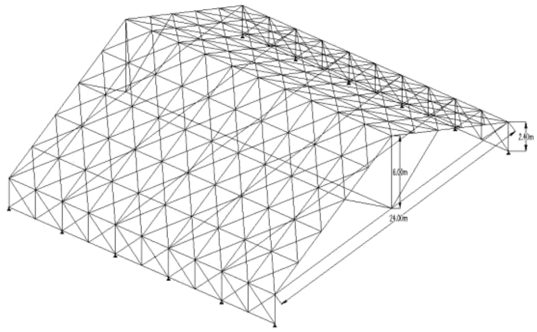
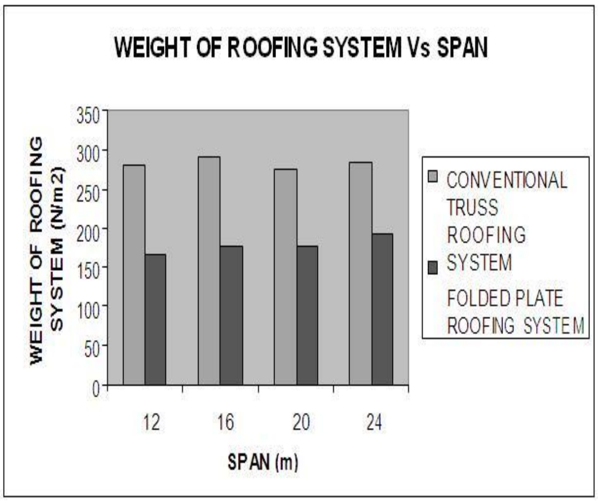


Figure.4.2 Steel frame folded plate-Roofing system for 24m span.

V COST COMPARISON

Table 5.1 Cost comparisons between the two systems of roofing.

Span	**Conventional Truss System**	**Folded Plate Roof system**	**Percentage Weight Reduction**
m	N/m^2	N/m^2	%
12	279.5	166.40	40.47
16	291.7	176.23	39.59
20	276.3	176.30	36.21
24	284.1	193.50	31.89



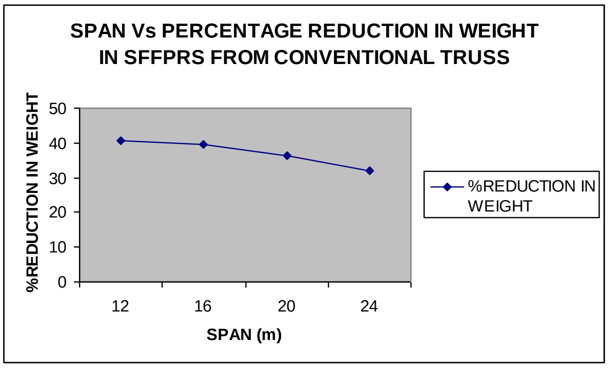


Figure 5.1 Span Vs Percentage reduction in

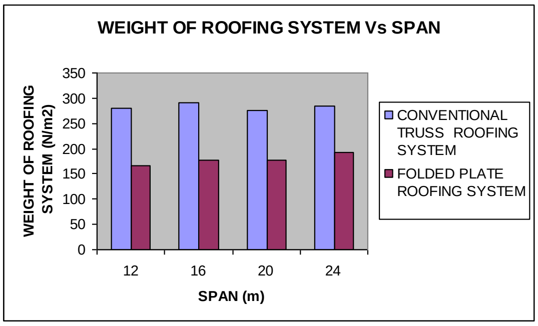


Figure 5.2 Weight of Roofing System Vs weight in SFFPRS from Conventional Truss Span

VI CONCLUSION

The project work in the present study can be summarized as follows:

1. Analysis of conventional truss roofing system and steel frame folded plate roofing system using STAAD. *Pro* 2004
2. Design of compression, tension and purlin members as per IS: 800-1984
3. Cost estimation for the given roofing systems for various spans.(Table.5.1)
4. Comparison of cost between the two systems of roofing.

The following results are obtained from the present study:

1. A table showing the percentage decrease in the weight of steel frame folded plate roofing system when compared to that of conventional truss roofing system when compared to that of conventional truss roofing system, for the same area.
2. A graph showing the relation between the weight (cost) and the span for conventional as well as folded plate roofing system.(Figure.5.1)
3. A graph showing the relation between percentage reductions in weight between the two roofing systems and the span of the roof.(Figure.5.2)

The following conclusions are made from the results obtained:

1. The steel frame folded plate roofing system (SFFPRS) is predominantly subjected to axial force and only a very negligible amount of bending moment is experienced, similar to conventional truss roofing system.
2. The analysis of SFFPRS does not involve any complex calculations and can be carried on easily using the Baer's method. It can also be analyzed as a simple space structure using software like STAAD.Pro.
3. The angle sections that are used for majority of the members in SFFPRS are lightweights, which are mostly used as secondary bracings in traditional roofing systems.
4. The laterals and the rafters alone required heavier angle sections, mainly due to the large values of their unsupported length.
5. The weight of the conventional truss roofing system is largely increased due to the provision of heavier channel purlins, to satisfy the deflection criteria.
6. In SFFPRS, lightweight angle sections that are commonly used as secondary bracings are used as purlin. And this greatly helps to reduce the weight of the roofing system.
7. Also the longitudinal members can also be used as purlins.
8. The cost of SFFPRS remains less when compared to that of conventional truss for any span.
9. The percentage reduction in weight of SFFPRS when compared to conventional truss ranges from 32% to 40%.
10. The provision of edge truss and lateral greatly reduces the axial forces in the members of Steel frame folded plate roofing system.
11. Upto 70% weight reduction can be obtained by replacing channel purlins with triangular purlin.
12. The weight of SFFPRS increases linearly with increase in span.
13. The increase in the weight of convention truss roofing system with the increase in span is not linear due to the effect of purlin weight.
14. It is found that the purlin weight increases with increase in the ratio between span and the spacing of truss

DISCUSSIONS

1. For industrial buildings, SFFPRS works out to be more out to be more economical than

its conventional counterpart.

2. Suitable ratio of span to spacing of truss as to be adopted for economical design of purlin.
3. Edge truss and laterals can be used to reduce the axial force and B.M in the structure.
4. Triangular purlins can be used to give a more economical design.
5. SFFPRS, in addition to being economical is also aesthetic and it provides large column free area.
6. The type of bracing chosen for SFFPRS should be such that it reduces the number of purlins needed.

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