DESIGN OF CURVED ARCH TRUSS WITH SECTIONS OPTIMIZATION FOR AUDITORIUM HALL

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ABSTRACT: Auditorium roof is covered by R.C.C Dome structure from ancient time due to which after decades when the auditorium is to be modified and extended than a large amount of scrape is gained which is waste and again a hard labor is required for reconstruction. Hence in order to overcome this problem a curved roof of steel structure is made in place of dome which can be easily extended when ever required with good strength. In order to increase the audience capacity inside the hall and to reduce the number of columns in between the audience for clear visibility as columns inside hall creates hindrance for visibility. A Span length of 30m is selected. In order to bring this concept a rectangular hall is considered with dimensions 30m × 68 m × 9m. A prototype is made is STAAD. Pro and the steel curved roof are checked for pipe and tube sections. Initially hit and trial method is used for section selections than optimization is done in STAAD. Pro and finally cost estimation is done and best section is suggested.
KEYWORDS: RCC, Dome, Truss ,Span

I. INTRODUCTION

In this modern era building dismantling and enlarging is very frequent in already constructed building because modification is needed for large space or any further extension for which whole structure cannot be dismantled and reconstructed. Hence a simple structure is to be made which can be modified with less labor work. Hence it can be said that for such structures steel sections are much easier sections which can be deal with. As steel sections can be easily connected and extended with less scrap where as in structures made of concrete are to be completely dismantled and reconstructed and scrap is also much as compared to steel structures. Hence auditorium hall study is considered here where the construction of dome structure is replaced by steel trusses and different sections of the truss are also tried to make the structure economical. Auditorium hall is a place of large gatherings. The auditorium hall is found to be have RCC dome coverings. Further it is seen that in auditorium hall span length of beams is small due to which columns are to be given at regular intervals which gives hindrance for the viewers to see the performances or the designer has to leave the space or adjust the sitting arrangement according to column positions. Hence to overcome this problem a curved Steel roof truss is replaced in place of RCC Dome and span length is increased to 30m. Initially a rectangular hall is considered 30m × 68 m × 9m and a Curved roof is designed with three rafters and bracings supporting the rafters. 13 trusses are used which are similar to each other and having spacing of 5.35 m C/C further the truss are supported by purlins which are straight and having three rafters and supported by inclined bracings at 2.35m C/C. The curved arch truss is rested on the column.

II. METHODOLOGY

The Study has been done for Arch Truss design for in order to overcome ancient truss design which is further optimized to give economical section selection. After studying about the auditorium problem is indentified, the necessity of roof with very long span to be provided so that the column in between should not put interference to the viewers so the idea was taken that a long span of 30m steel section should be applied on the roof. In order to accomplish the advantages of the new arch girder slab system over other conventional slab systems, the effort has been made to design truss members and checking suitability using STAAD. Pro. The models of arch truss with steel sections using tube, pipe sections have been made and their economy is considered comparing cost using weight parameter.

The purpose of this analysis is to compute a steel Arch roof truss with proposed 30m×68m×9m over auditorium R.C.C slab and to give a large area under the truss for the audience to see the performance without any hindrance and in order to increase the capacity of audience.

An auditorium sitting area is considered with 30m× 68m. Truss is at 5.35m spacing and truss support rest at inclined beams. Purlins are welded between the truss having spacing of 2.36m. So, that the C.G.I sheets applied at the top can distribute their loads to the bottom. Total 13 trusses are used to cover complete area. In designing of the trusses various Indian standard section are used mainly Tube, Pipe Section are considered and economical study is also done. Truss is designed in the STAAD. Pro Software and sections various sections are studied by hit and trial method and further optimization of the sections are also studied so that the correct sections are placed at right places and the final design is very economical. After which the deflection of beams and nodes are further studied. The cost considerations are also done for different sections used in the trusses.

Plan and Elevation of Arch Roof Truss considered for Analysis.

The auditorium is considered as rectangular in shape and it is planned in such a way that the maximum distance between the support is taken as 30m i.e span length. To increase the capacity of viewers and similarly of the auditorium length is taken as 68 meters. The no of trusses is 13 with center to center distance of 5.35m and each truss is resting on two columns. Hence total number of columns is 26 and columns on one side are 13.

Central height of arch roof truss is 3.75m with slope angle 280. It should be noted that for economical study a comparison is done between Indian standard sections (Tube and Pipe) using reference available in STAAD. Pro software.

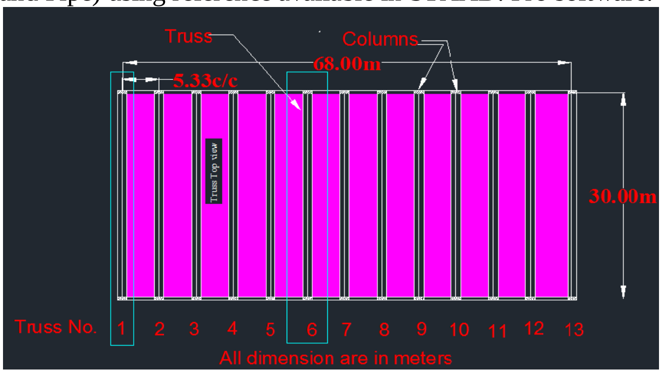
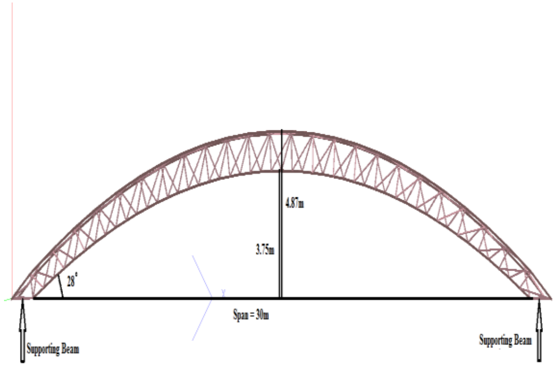


Fig.3 a) Line plan of hall over with roof truss



b) Front Elevation of Arch Roof Truss located at 26m from the end.

Data of the Model
Truss configurations

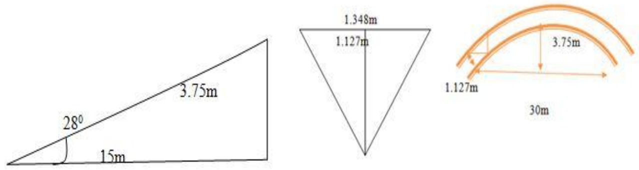


Fig No. 4.11 Truss configurations showing cross section and elevation of Truss

Let θ be the inclination of the roof with the horizontal and central height of the rafter be 3.75m.Then,By using formula, Central height we get from formula,

Span/ height = 8 , Hence, 30/8 = 3.75m

Again, Angle = Arch/Radius , Sin θ = 15/3.75 or θ = 28°4'

Load Calculations

Here we will consider only two types of loads that is dead load and live load. Dead load will from the self weight of the Arch truss model and the C.G.I sheets which are fixed on the truss which will rest on the truss and the load will be applied on the nodes of the roof truss.

The following design procedure is use in the design of loads.

Step 1. Dead load = Weight of C.G.I sheets + Weight of Bracings + Self weight of Roof Truss

Step 2. Live load = Taking it as 500 N/m2

Step 3. Wind load = wind load is not considered as in this case we are assuming that the structure is below about 11m.

Analysis

- To check the modified roof for a plan of auditorium hall of size 30m×68m.
- To analyze the members using software STAAD. Pro for shear and bending, nodal displacement.
- Whole structure is checked for self weight along with live load i.e. CGI sheets which are used as roof covering material are loaded on the truss model and analyzed.
- The truss model designed is checked for its stability.
- Indian standard steel members are used and best section is suggested for the model.
- The complete structure is optimized and estimated for economy.

For above analysis following two cases are considered for analysis as below:

Two methods are also considered

The prototype truss made is assigned with both pipe and tube sections available in IS code with hit and trial method and studied for economical section.

Case I: - Truss Sections bracing and purlins are assigned with Pipe section

Case-II: - Truss sections bracings and purlins are assigned with Tube section

Again prototype truss assigned with pipe and tube sections are further optimized and again analysis is done for economical section.

With reference to IS codes following sections are taken for hit and trial methods for analyzing the truss model as tabulated below.

Method 1: By Hit and trial method.

1 For Both Case Sections selected:

Table 1 Pipe sections selected for Hit & Trial method

S. No	Location of section	Tube Section details(for Bracings + for Rafters)	Pipe Sections (for Bracings + for Rafters)
1	Used in Bracings	TUB80403.2	PIP603L
	Used in Rafters	TUB50252.9	PIP1016M
2	Used in Bracings	TUB75753.2	PIP213M
	Used in Rafters	TUB40402.6	PIP337L
3	Used in Bracings	TUB60402.9	PIP213M
	Used in Rafters	TUB32322.6	PIP424L

B) Optimization of pipe section: optimization is done by STAAD. Pro and is shown for truss no.1 as below:

Table 2 Optimization of Pipe sections by STAAD Pro. For truss no.1

Beams	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized ratio Actual/allowable
25	PIP3556H	PIP2191L	0.935	1	0.935
26	PIP3556H	PIP1524M	0.939	1	0.939

Beams	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized ratio Actual/allowable
27	PIP3556H	PIP1270L	0.836	1	0.836
28	PIP3556H	PIP889M	0.85	1	0.85
29	PIP3556H	PIP483L	0.906	1	0.906
30	PIP3556H	PIP483L	0.846	1	0.846

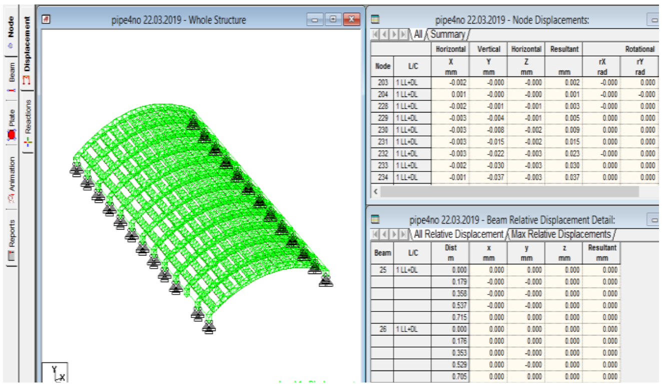


Fig.4a)Nodal Displacement & Beam Displacement resulted

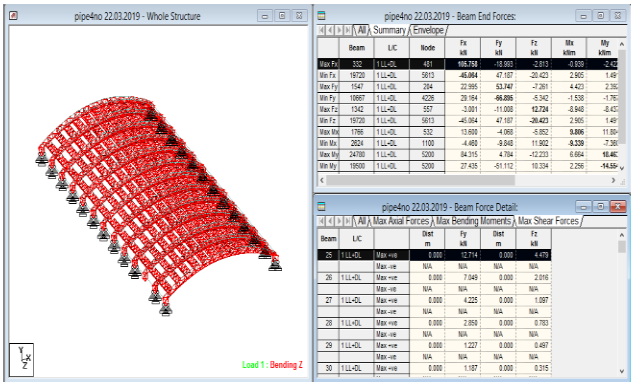


Fig 4 b) Beam End Forces & Beam Force Details resulted from STAAD.

Pro Analysis for pipe section

Case-II: - Truss Sections bracing, purlins are of Tube section

Details of Tube sections selected for analysis and optimization:-

After assigning the whole structure is checked for safety and load bearing. After which the beams are optimized so that the section required is placed as required and economy of the structure can be maintained.

Table 3 Optimization of Tube sections by STAAD Pro. For truss no. 1

Beams	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized ratio Actual/allowable
25	TUB1501506	TUB1501506	1.051	1	1.051

Beams	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Normalized ratio Actual/allowable
26	TUB1501506	TUB140804.5	0.999	1	0.999
27	TUB1501506	TUB127503.6	0.821	1	0.821
28	TUB1501506	TUB80403.2	0.971	1	0.971
29	TUB1501506	TUB38382.6	0.949	1	0.949
30	TUB1501506	TUB45452.9	0.919	1	0.919

Similarly all the sections are optimisized as the data is very large so only few members details are given below.

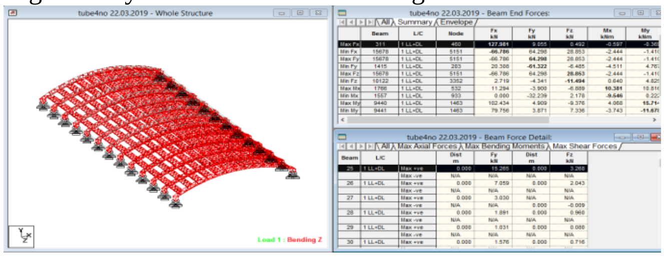


Fig.4 Beam End force & Beam force details resulted from STAAD. Pro Analysis for Tube section

Design of Columns

RCC columns are designed to support the RCC beam on which the rafters rest with a bearing plates. Load transferred by the truss will be transferred to the column hence simple column is designed in such a way that the rafters can be rest directly rest on the column The height of the column is kept 9m and wind effect is also neglected. For 68m length of Auditorium 13 trusses will be designed and spacing of the truss will be 5.35m center to center hence the trusses are placed in such a way that they rest on the center of the column.

4.13 Connection of Steel Truss and base RCC beam

The association between the main rafters and RCC beam section on the base support is considered as hinged support and loads are transferred from the top covering material to the main arch truss rafters than to the supporting RCC beam structure which will further transferred to the RCC column as shown in the figure below.

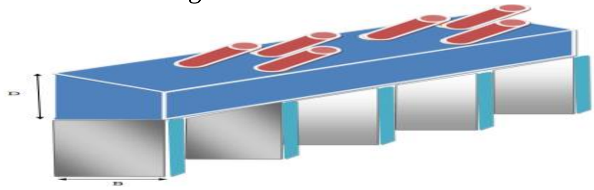


Fig. 5 Inclined RCC beam for supporting three rafter ends

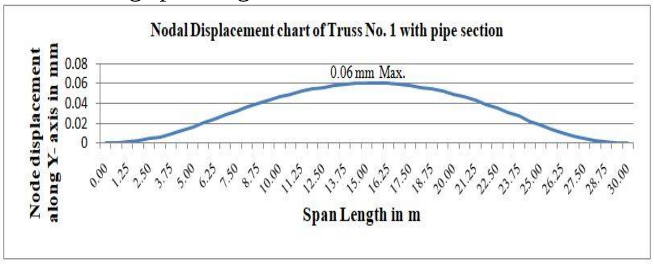
4.14 Column and Foundation

The column and Foundation is considered for general design as for other building structures and no changes are made to this section.

4.15 Graphical result analysis and cost estimation

In the end all the truss sections are considered altogether and the loading is done on the roof with C.G.I sheets and loads are applied on the sheets by which the loads are distributed on the rafter from sheets and on the purlins which is further distributed to the columns. Here in diagram shown is only for analysis purpose in STAAD.

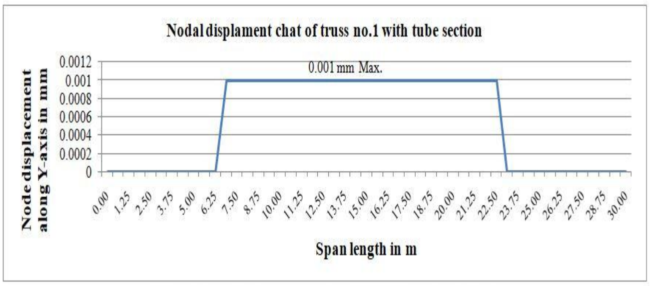
Max. Nodal displacement of Pipe Sect. Truss at different interval along span length



Graph 5 Nodal displacement along Y-axis in pipe section for truss no.1

The above graph shows the nodal y-axis displacement of the truss no. 1 at every 0.67m length along the span .when the truss members are assigned with Pipe section. In the above graph X-axis is showing the distance in meter of span length which is starting from zero meter and ends at 30m and Y-axis is showing nodal displacements in mm. The maximum value of the displacement is seen at 0.06 mm at 15m of the span that is in the center of the truss.

Max. Nodal displacement of Tube Sect. Truss at different interval along span length



Graph 6 Nodal displacements along Y-axis in Tube section for truss no.1

The above graph shows the nodal y-axis displacement of the truss no. 1 at every 0.67m length along the span .When the truss members are assigned with Tube section. In the above graph X-axis is showing the distance in meter of span length which is starting from zero meter and ends at 30m and Y-axis is showing nodal displacements in mm. The maximum value of the displacement is seen at 0.001mm at 15m of the span that is in the center of the truss.

Case I- when the whole structure is designed by Pipe section

Table no. 5 Estimation of total quantity of steel in pipe section

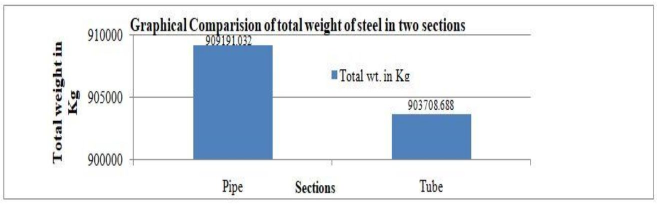
S.no	Section of structure considered	Total no. of section similar in whole structure(A)	Quantity for one section(B) (Kg)	Total quantity (Kg) (A×B)
1	Truss	13	31821.16	413675.08
2	Purlins	144	3441.083	495515.952
3	Total steel			909191.032

5.6.3 Case II- when the whole structure is designed by Tube section

Table no. 6 Estimation of total quantity of steel in tube section

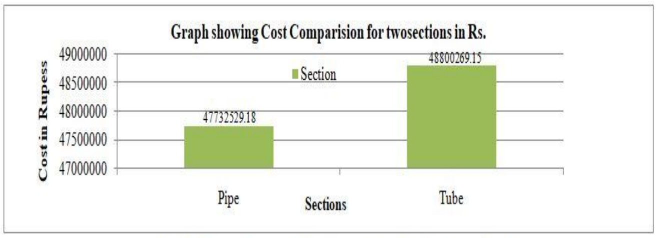
S. no	Section of structure considered	Total no. of section similar in whole structure(A)	Quantity for one section(B) (Kg)	Total quantity (Kg) (A×B)
1	Truss	13	12511.408	162648.304
2	Purlins	144	5146.252	741060.384
3	Total steel			903708.688

Graphical representation for cost evaluation for auditorium roof



Graph 5.16 Comparison graph showing total weight of steel used in Roof

In the above graph a comparison is shown for total weight of different sections of steel used for truss model. In the graph sections are defined on the X- axis and in Y-axis weight is defined. It is seen that for the prescribed model .Steel used for I-section is maximum in weight and minimum steel weight is for channel section. Therefore it is clear that I-section is very heavy for the truss model and channel section will have less weight in comparison with other steel sections.



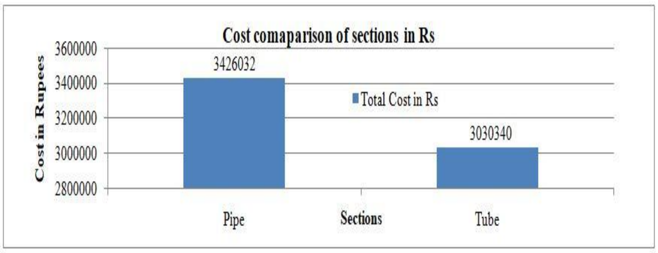
Graph. A comparison graph showing cost of roof with sections selected

On the basis of weight cost is estimated so in the above graph the cost comparison between all the four sections used for the truss model is estimated and it is seen that I section is very uneconomical and channel section is very economical section when hit and trial method is used for analysis process in the above graph it is seen that on the X-axis is showing four sections and Y-axis is showing rate in rupees.

Comparison of sections after optimization and cost comparison

Table no. 5.11 Total cost of steel for complete roof with optimized sections

S. no	Section	Total Cost in Rs
1	Pipe	34,26,032
2	Tube	30,30,340



Graph 5.18 A comparison graph showing cost of all four sections in case of optimization method

In the above graph a comparative graph is plotted between two sections used for the truss model after optimization and it is seen pipe section is very uneconomical and comparative graph shows that pipe and tube is giving nearly same cost. it is seen that tube section is most economical section when compared with pipe sections but it is found that few members are failed during the design. Hence more economical section is pipe section which also stable and can resist the load on it.

III. CONCLUSION

The Arch truss is worked out for two different configurations for minimum dead load of material used with minimum cost of steel for considered area. Hence following conclusion are made.

- Optimization technique is used in STAAD. Pro again and adequacy checked.. It is found that though Tube section is more economical but it failed in design. It is seen that few members failed in load bearings. After tube section best section which gave satisfactory result is Pipe section in all aspects
- Hence we can conclude that after comparison of tables in result Pipe section is best section for the required area 30m×68m×10m to make Arch roof truss and pipe sections are safe in load bearings and cost effective in comparison with other considered Indian sections.

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