OPTIMIZATION IN DESIGN AND ERECTION OF HANGAR STRUCTURE

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ABSTRACT

The construction industry consists of unique and complex projects. The success of the project not only lies in its design but in its practical execution as well. Design of the structure should overcome the existing problems faced in executing it. Hangar structure is a steel structure used in airports for conducting maintenance works and other operations relating to aircrafts. The objective of this project is to carryout optimization in the design and erection of hangar structures. Optimization in the design is done by using sections that can bring down the steel tonnage effectively. In the process of erection, an attempt has been made to optimize the design by taking into consideration various erection methodologies and arriving at the most suitable one. To carry out the same, an existing hangar structure is analyzed using STAAD PRO. V8i. An existing hangar structure at Mumbai International Airport is chosen for this study. A detailed analysis considering the various loads acting on the structure has been carried out. Numerous trials were done to arrive at the most optimum shape and member size. It is found that rigorous analysis and design leads to a material steel saving of 14.36 %. This also leads to reduced handling and erection costs.

INTRODUCTION

In the existing structure, I – sections and built up steel sections have been used. Considering the economic factors, there is a need to reduce the steel consumption in order to bring down the construction costs. Circular Sections are known to possess high torsional capacity. Our aim is to use Circular Hollow Sections to achieve the aforementioned goals. Secondly, the costs for erection of the structure contributes a huge amount to the total project cost. There is a need to study various available erection methodologies and choose the most economical one among them in order to reduce the project cost.

OBJECTIVE

The main objective of the study is to optimize the structure in terms of design and erection. This is achieved by understanding and analysis of the existing structure in order to optimize the design in terms of strength and economy by the use of alternate member sections such as circular hollow sections(CHS). Secondly, the erection methodology of the existing structure is studied and various other methodologies are also investigated in order to arrive at a suitable methodology for the optimized structure. The structure is then analysed for this methodology and the member sections are modified accordingly.

UNDERSTANDING OF THE STRUCTURE

An existing RCC structure has been used as a Hangar to house two A 380 aircrafts as shown in the Figure 1. It is observed that the tail of the parked planes protrude beyond the existing structure. Therefore, this steel truss is built as an extension to the existing RCC Structure in order to cover the protruding tail of the plane parked at the Hangar.

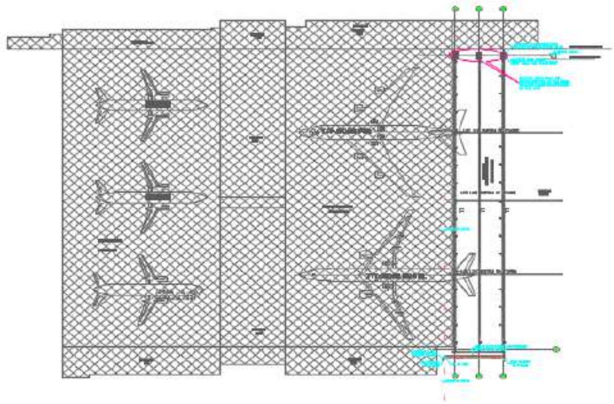

Figure 1 Floor Plan of the Existing Hangar Structure

The Hangar Structure chosen for this study has a span of 148 m with one end hinged and the other end being fixed. The fixity is attained using a steel column that is embedded on to a 12m high Reinforced Cement Concrete Column. It consists of three bottom and top chords running parallel at a distance of 10m from each other, that are interconnected using steel bracings. Figures 2 and 3 show the elevation and plan view respectively.

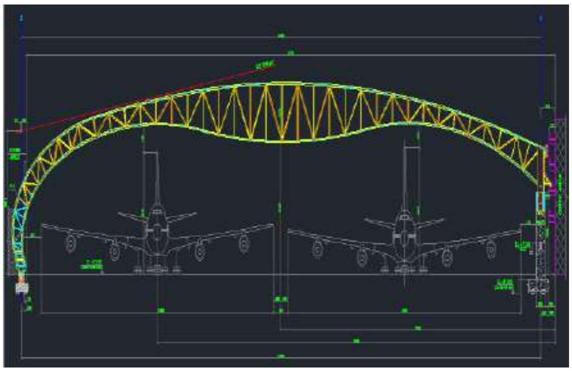

Figure 2 Elevation

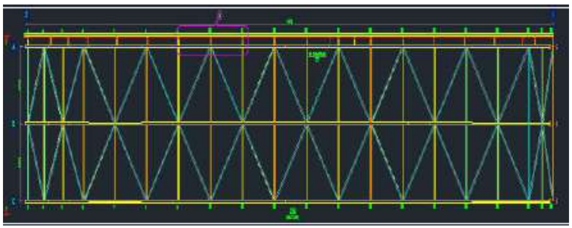

Figure 3 Plan View

ARRIVING AT THE GEOMETRY OF THE STRUCTURE

The BMD indicates two points of contraflexure which in turn allows us to adopt optimised sections - a minimum cross section at the points of contraflexure and maximum cross section at areas where large bending moments are produced. According to the architectural requirement, the structure should not go beyond the obstacle limiting surface (OLS). Meanwhile, the structure cannot extend below the clearances for the tail of the aircraft. Therefore, the Hangar structure should be accommodated within the shaded region as shown in the Figure 4 below.

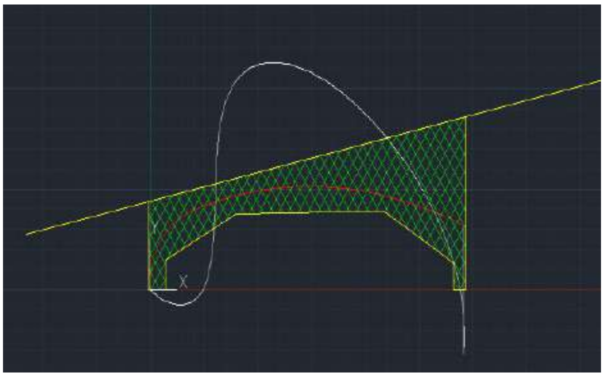

Figure 4 Representation of the Locational Constraints and BMD of the Centre Line Diagram

MODELLING OF THE STRUCTURE USING STAAD. Pro

The hangar structure is modeled using STAAD.ProV8i. On application of the design loads to this model, it is found that the model was perfectly stable when analysed using STAAD Pro.

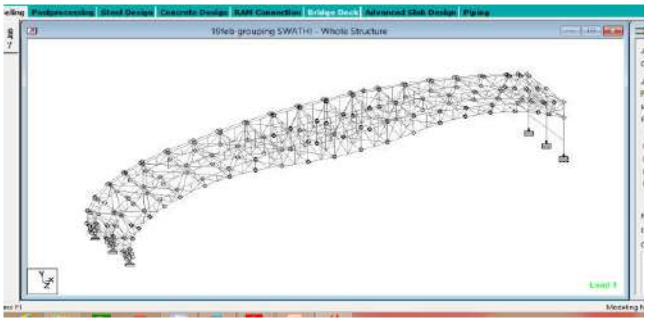

Figure 5 Three Dimensional Model developed using STAAD. Pro

ANALYSIS

The Original Structure was analyzed using BS 5950. Hot rolled steel built up members have been used in the structure. It allows some sections to fail upto a ratio of 1.5. In order to strengthen the failing section, stiffeners are provided. To account for the deformations greater than the permissible limit, method of pre cambering is adopted. The original structure weighs 383 tonnes.

DESIGN

The design could not be performed using user defined prismatic sections in the IS 800 LSD. Moreover, the sections available in the library did not pass the structural stability criteria. Majority of the beams failed in the ratio of 1.7 which in turn does not give room for reducing the steel tonnage. Hence, optimization was done using BS 5950 since IS 800 LSD is found to be conservative.

We have used circular hollow sections (Pipes) that are available in the British Steel Sections Library, in order to reduce the steel tonnage. The structure does not allow any section to fail. To account for the deformations greater than the permissible limit, method of pre cambering is adopted. The optimized structure weighs 326 tonnes.

ERECTION ENGINEERING

While choosing a suitable erection methodology, number of factors have to be considered. Firstly, the spliced member, during the process of erection, has to be structurally stable at all stages. Secondly, the lifting capacity of the crane should be chosen accordingly. Thirdly, the space available at site for the movement of the crane should also be considered. Detailed analysis of a number of such factors is required in order to adopt a suitable erection methodology for a steel structure.

VARIOUS ERECTION METHODOLOGIES CONSIDERED

A study of various erection methodologies, available in today's construction world, was carried out in order to arrive at a suitable erection methodology for the optimized structure. Among many available methods, the following method was found to be more appropriate.

Erection using Temporary Supporting Towers

This is the method adopted for erecting the original structure. In this method, the members are spliced at regular intervals. These spliced members are erected in a particular sequence with the help of temporary supporting towers. Once the erection is completed, the towers are de-propped carefully. Figure 6 shows the arrangement of temporary towers used for the erection.

Advantages
This method is the most suitable as it is both structurally stable and an economically viable option. Since the optimized structure has a reduced tonnage, the capacity of the temporary tower as well as the crane gets greatly reduced. Meanwhile, the members would also be stable in the intermediate stages of erection without introducing much change in the steel tonnage.

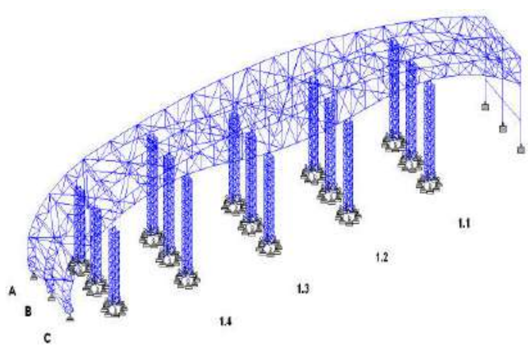

Figure 6 3D View of the Structure over the Temporary Supports

ERECTION OF THE OPTIMIZED STRUCTURE

The optimized structure is being analysed stepwise as it is erected in segments. In Part 1 of every step, the segment is lifted using a crane. The two points, where the segment is being lifted, are at one thirds distance from the Centre of Gravity of the segment. In Part 2, the segment is erected and supported using temporary towers without the placement of diagonal bracings across three parallel chords. In Part 3, the segment is erected and supported using temporary towers after the placement of diagonal bracings across three parallel chords. In each of the steps, the stage at which some of the beams fail for temporary cases is named as a "trial" file. The section properties of failed beams are then modified to make the structure stable at every stage. During erection, the self – weight of the erected structure and the wind loads associated with the structure are taken into consideration for analysing its stability.

Analysis of the erection of Splice 3 is shown as an example :

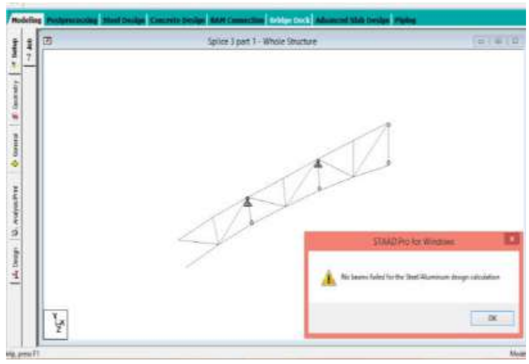

Figure 7 Splice 3 Part 1

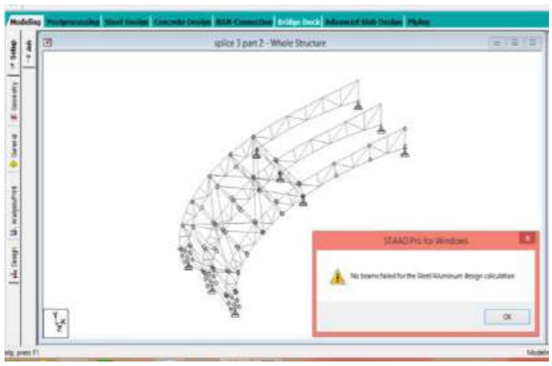

Figure 8 Splice 3 Part 2

Splice 3 part 3 trial, when erected, is unstable for the given load conditions as shown in Figure 9. The following beams have failed at ratios as given in Table 1

Table 1Ratio Of Failure

Beam No.	Ratio of Failure	Section Property
1212	1.141	PIP885.0
1318	1.013	PIP885.0

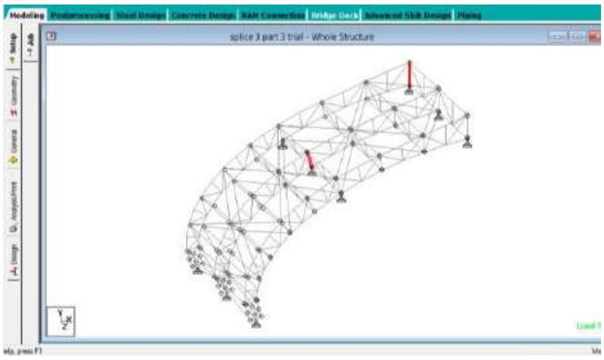

Figure 9 Splice 3 Part 3 Trial

After modifying the section properties of the failed beams as given in the table 2, the splice 3 part 3 is stable when erected.

Table 2 Modified Section Property

Beam No.	Modified Section Property
1212	PIP1145.0
1318	PIP886.0

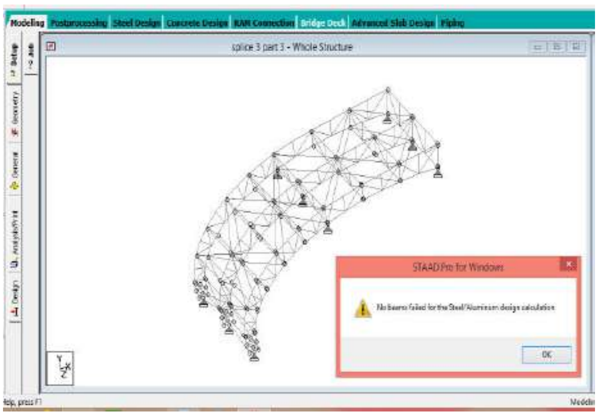

Figure 10 Splice 3 Part 3

After the removal of supports and application of real time loads, the erected segment is unstable for the given load conditions. The final erected segment is stable for the given load conditions after modifying the section properties of the beams.

RESULTS AND DISCUSSIONS

From the analysis carried out various parameters such as steel tonnage, structural performance and erection process has been compared for the original and optimized structures.

STEEL TONNAGE

The steel tonnage for the original structure and the optimized structures before and after erection have been depicted in the graph below:

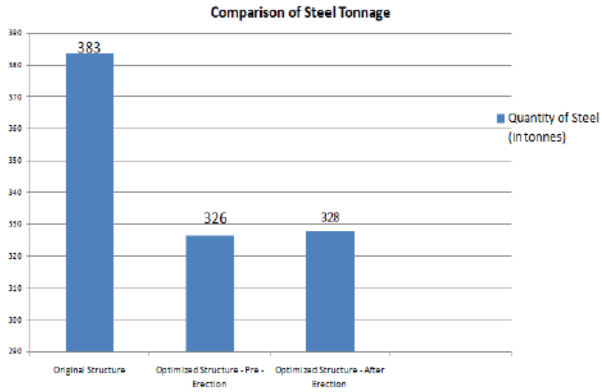

Figure 11 Comparison of Steel Tonnage

STRUCTURAL PERFORMANCE

The vertical displacement at nodes for the original structure is found to be 570mm while that of the optimized structure is found to be 517mm. The permissible limit of displacement is 370mm (L/500). The rest of the displacement is accommodated by the Pre - Cambering Method. The values of support reactions and forces at beams for the optimized structure are lower than that of the original structure of the order of 10 kN.

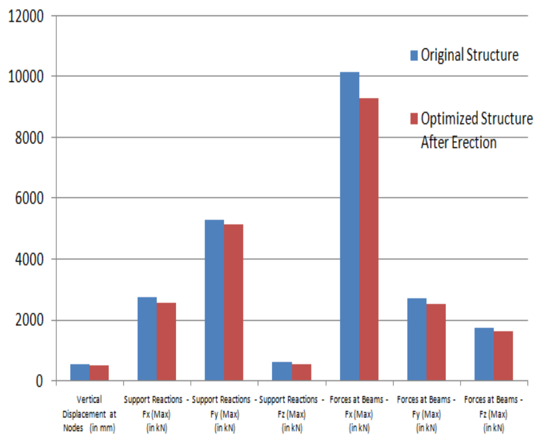

Figure 12 Structural Performance

ERECTION OPTIMIZATION

Two parameters are taken into consideration while analysing the extent of optimization performed in the process of erection. These parameters are namely, load on the temporary tower and load to be lifted by the crane. The load on the temporary tower for the original structure is 25.53 tonnes. On the other hand, the load on the temporary tower for the optimized structure is 21.87 tonnes which shows a reduction of 14.34%. Secondly, the load to be lifted by the crane for the original structure is 50 tonnes with a boom length of 16m. On the other hand, the load to be lifted by the crane for the optimized structure is 30 tonnes with a boom length of 16m. There is a reduction of 40%.

Built Up Members have been used in the original structure contributing to a significant increase in steel tonnage. On the other hand, the optimized structure has achieved a reduced steel tonnage using Circular Hollow Sections. Moreover, these sections have an increased torsional capacity.
Secondly, the original structure has used bolted connections. Bolted connections have a number of limitations such as introduction of stress concentration, increased steel tonnage etc. Such limitations are eliminated in the optimized structure due to the use of node connectors.

CONCLUSION

From the detailed analysis and investigation carried out on the steel hangar structure, the following conclusions are drawn :

- Rigorous optimization methodology leads to a reduction in steel tonnage by **14.36%**
- The serviceability of the final erected structure has also been improved. The vertical displacement has reduced by **9.29%**
- During erection, the load on the temporary tower has been reduced by **14.34%**
- The load to be lifted by the crane has also been reduced by **40%**

The original structure used built up sections. But with the increasing awareness and availability of Circular Hollow Sections, the construction industry should realise the need to switch to such sections in order to cut down the project cost. From the results obtained through this study, it is seen that the optimized structure has brought down the cost related to temporary tower design and required crane capacity drastically. Moreover, the use of node connectors is also an added advantage. At the same time, the structural performance of the CHS is also better than the built up members in many aspects including torsional capacity and deflection.

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