Structural study of a Multipurpose Auditorium with Modified lenticular girder Roof

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Abstract- **The long span roof structures without an intermediate column support is developing over the years. The conventional roof trusses can cover effectively for a span of 30metres. For large span structures modified lenticular girders were found to be effective to withstand the heavy bending moment. Especially in an auditorium like structures intermediate columns would obstruct the view of the audience to the stage. As per the design standards a rectangular auditorium of dimension 80m X 50m is planned. The roof chosen is a modified lenticular girder with the pre stressed cable supported to the bottom chord. On analysis this type of roof is found to be more effective than a conventional truss and lenticular girder. The connection between the steel girder and the concrete beam is made of an embedded steel anchorage to withstand the energy dissipation and ductility. The embedded steel anchorage acts as a hinged support to transmit the loads and resist the moment. This steel anchorage offers a high resistance to the wind loads. The columns and foundations are designed in a conventional method to transfer the loads to the soil.**

Keywords: **Auditorium; steel; lenticular girder; Conventional method.**

I. INTRODUCTION

Multipurpose auditoriums are one of the most important areas in the institutions around the world. This type of auditoriums is extensively used for lectures, concerts and cultural events. The structural and acoustical aspects of this type of auditoriums have a great variation with other types of auditoriums, since it needs to accommodate a variety of events with acoustics suitable for all types. In the economical aspect of an institution, it is of great advantage to have a multipurpose auditorium instead of having various auditoriums of different types. For greater span truss with the bottom chord are inclined towards the mid span for withstanding the tensile and bending moment. A composite structure of steel truss supported over a concrete column is considered to be highly sustainable to withstand the structural load. As a replacement of conventional type of trusses modified lenticular shaped girders [10] are introduced to withstand the heavy bending moment occurring in long span structures [1]. The composite structure of a steel truss or girder over a concrete wall has developed recently. These are adapted as an alternative to conventional structures owing to its less structural weight, speedy construction and ability to bear high bending moment without any column interruption for long spans [2]. The connections can also be established on concrete beam to cut down the cost and increase the structural efficiency. Studies reveal that for biaxial loading conditions reinforced concrete columns are more efficient to withstand heavy compression loads [4]. The columns can be supported over any type of footing depending upon the behavior of soil [5].

II. STRUCTURAL ASPECT

A. Roof Structure

The proposed roof structure is a steel girder, suitable for long spans and composite structures [1]. This steel structure is cost effective and resist large bending moments. By applying pre stress forces on the top and bottom chord of the girder the ability to withstand the loads are maximized. The top and the bottom chords shown in fig 1are made of pre stressed cables and anchored at the ends to transfer the loads completely. This system can also be used with conventional members like purlins and rafters to form the roof structure [1]. The structure is a deformed shape of a lattice truss with the top and bottom girders following a parabolic path. For analysis the top chord is considered to be normal and the bottom chord is supported by pre stressing cables shown in fig 2 [1]. The top and bottom chords were made up of two tubular beams of size ISTUB1501506 and a vertical steel plate 150 x 6 mm. The vertical struts and diagonal cables were made of cross section ISTUB1251256. The pre stress cables were chosen by area 50cm^2.

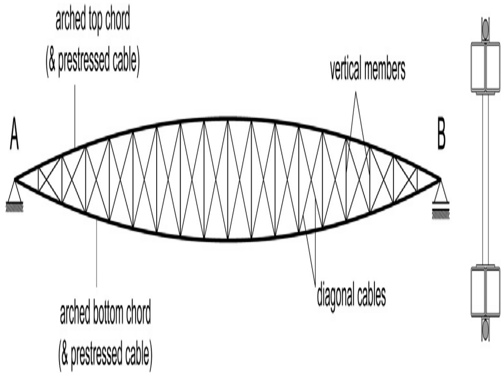


Figure 1. Girder with top and bottom chord

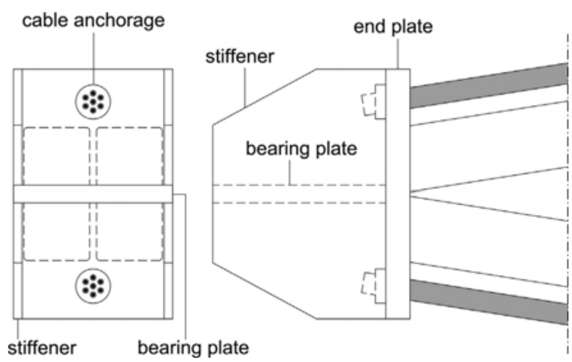
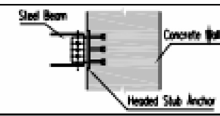
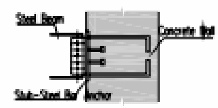
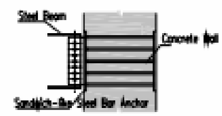
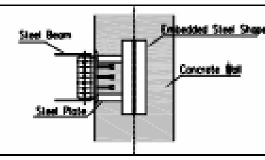


Figure 2. End Connection of Girders

B. Connection of Steel Girder and Concrete Beam

The lack of experimental studies of composite structure of steel girder over a concrete structure has resulted in the implementation of such composite structures in less or no seismic regions. The connection between the concrete beam and steel girder is considered as hinged during analysis [2]. The Finite Element analysis indicates a resisting moment transferred to the columns through the connection which shows that the actual moment will be larger than the calculated value [3]. The types of connections are given in the Table 1 [2]. These types of connections are termed as Embedded anchors. It is found that the Type 4 indicated in the table is the most advicable connection due to its high anchorage capacity, energy dissipation and ductility on comparison with other types [2].

TABLE 1 DIFFERENT TYPES OF BEAM WALL CONNECTION

Type	Types of Steel Beam-Concrete Wall Connection	Mainly Applied to
1		Light Load Secondary Member
2		Ordinary Member
3		Major Member
4		Heavy Load Major Member

C. Column and Foundation

The beam column joints follows the regular conventional pattern to transfer the load from the roof to the footing. The columns and foundation are also designed on a conventional basis for its purpose to just transfer the loads to the ground.

D. Acoustics

The acoustical design is an important considerable factor in the multipurpose auditorium. Lecture auditoriums are distinguished from other types of auditoriums by the usual fixed positions of both sound source and listeners. It is noted that architectural acoustics in general and acoustics of an auditorium in specific has two main principles. The first one to provide a good acoustical environment inside the room, which is known as sound absorption. The second one is between the room and its surroundings which is known as sound isolation. The main objective of these two principles is to provide a good acoustical environment in the auditorium. The architectural design includes a detailed study for sight distance and angles that enable every person in the auditorium at any position on it to see every point without any obstruction. Using the natural lighting and ventilation, wooden cladding, marble and granite as a finishing material the acoustics of the auditorium can be maintained.The reverberant sound in an auditorium dies away with time as the sound energy is absorbed by multiple interactions with the surfaces of the room. In a most of the reflective room, it will take longer for the sound to die away and the room is said to be 'live'. In an absorbent room, the sound will die away quickly and the room will be described as acoustic 'dead'. But the time for reverberation to completely die away will depend upon how loud the sound was to begin with, and will also depend upon the acuity of the hearing of the observer. Reverberation time is defined as the time for the sound to die away to a level 60 decibels or (1/1,000,000) below its original level. Over the audience and over the stage, ceiling clouds and panels produce balanced and blended sounds for a variety of venues, resulting in a rich, directed sound that the discriminating audiences have come to expect.

III. RESULTS AND CONCLUSION

A. Roof Structure

The steel girder was placed over a clear span of 44.6 m. The girders were placed at regular intervals of 3m. The analyzed plan of the Auditorium is given in fig 3 and Deformed Shape of Lenticular Girder showing member forces shown in fig 4. Also modified Lenticular Girder shows member forces shown in fig 5. Finite Element Analysis of the proposed structure using STAAD.Pro was done and a comparison with the conventional truss and lenticular girder yielded the results shown in table 2. During analysis the end connections of the girders were assumed to be hinged.

TABLE 2 MAXIMUM VERTICAL DISPLACEMENT AND MEMBER FORCES

Load Cases	**U_y (mm)**	**M_y (KNm)**	**N (KN)**
Case 1 (Conventional Truss)			
Dead load	-150	9	-978
Dead Load + Wind Load	171	12	-962
Case 2 (lenticular girder)			
Dead load	-70	11	-972
Dead Load + Wind Load	72	27	-1148
Case 3 (Modified lenticular girder with pre stressed bottom chord)			
Dead load	0	0	-998
Dead Load + Wind Load	59	24	-1245

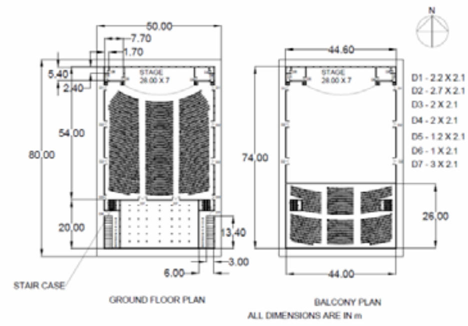


Figure 3. Plan of the Auditorium

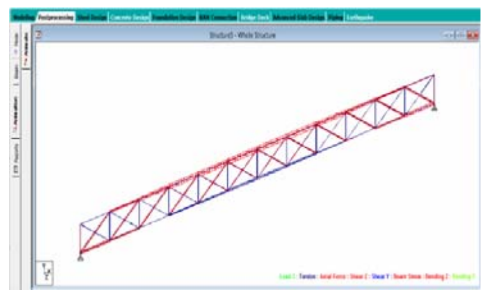


Figure 4. Deformed Shape of Lenticular Girder showing member forces

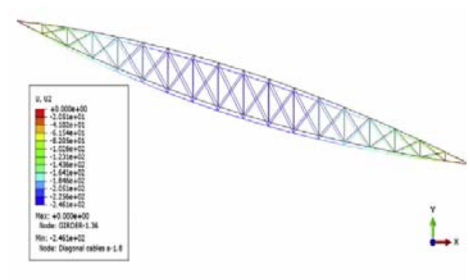


Figure 5. Deformed Shape of Modified lenticular girder

B. Steel Girder Concrete Beam Connection

The connection of the steel girder with the concrete beam is adopted to be the type 4 described in Table1.While Designing Special considerations [3].

C. Column and Foundation

The column and the foundation are designed in a Conventional way as per the guidelines laid down by the Indian Codes [4].

D. Acoustics

The acoustical provisions are made as per Indian Code [11].

IV. REFERENCE

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AUTHORS PROFILE

Priya. A.K, Assistant Professor, KPR Institute of Engineering and Technology, Coimbatore. She got a gold medal in PG Environmental Engineering and Management in Anna University. She completed her doctorate from Anna University, Chennai. She acts as a researcher and carried out many research work in different areas under Civil and Environmental Engineering. Also, she is the member in various learned bodies like Indian Water Works Association (IWWA) and Indian Society for Technical Education (MISTE).

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