MODELLING AND ANALYSIS OF STADIUM FOR A RETRACTABLE ROOF

Chandrika P, 1Keerthana R, 2 Rashmi T.M, 3 Hruthik R, 4Santhosh V
1Asst.Prof, 2UG Student, 3UG Student, 4UG Student, 5UG Student,
1Department of Civil Engineering
1Cambridge Institute of Technology, Bangalore, India

Abstract: This study presents a detailed analysis of retractable roofs. The retractable roof is a versatile architectural feature designed to provide flexible shelter and climate control for various structures, such as stadiums, arenas, and outdoor spaces. This innovative technology allows for the seamless transition between open-air and covered environments, offering protection from adverse weather conditions while maintaining an open-air experience when desired. It aims at enhancing the overall spectator experience and ensuring uninterrupted gameplay, regardless of adverse weather conditions. This innovative system involves mechanized panels and sections that can be opened or closed. The length of retractable roofs increases with the demand for more flexible and light construction, and such requirements mark retractable roof structures more sensitive to wind actions. The project outlines the potential impact of this innovative solution on the sports industry and multipurpose events.

Index Terms - Analysis, design, modeling, roofing material, STAAD PRO, trusses, retractable, Stadium.

I. INTRODUCTION

Retractable roof stadiums in North America have roofs that can open and close. When the weather is in good condition the roofs are open if the weather is in bad condition such as rainy fog etc. The roof will be closed. During a match, if there is a sudden rain then the roof can be closed so that everyone can enjoy the game and even players can continue playing.

There are currently just 13 retractable roof stadiums in the US, 7 in Japan, 18 in Europe, and 6 in Australia. For Indian cricket stadiums, there isn't even a single reference paper on retractable roofs. The fact that rain, fog, and other weather conditions can disrupt a cricket match is a major issue. We have created a model of a retractable roof for a proposed cricket stadium, even if it is uncommon for the match to be extremely essential to work on this. With a modest investment, an existing stadium may implement this concept. The retractable roof structure we built has several benefits, including the ability to open or close for 25%, 50%, 75%, and 100%. According to Anita Pawalak and Keystyna Romaniak they mentioned about the use of two four bar linkages that can accommodate the impact of sudden strong wind in the journal of Class II mechanism in the construction of retractable roofs for ports stadium [1]. And Bhavana mentioned about the analysis of retractable roof for 25%, 50%, 75% and 100% in the Staad pro software to determine the total stresses at the end beam in the journal called Analysis of retractable roof [2]. Man Liu and Qiu-Sheng Li discussed about the wind tunnel test, full scale measurement and computational fluid dynamics. In this they talked about the retractable roof of 8 petal like components, which have 4 retractable states i.e., 0°, 15°, 30°and 45° in the journal Evaluation of wind effects on a large span of retractable roofs stadium by wind tunnel experiment and numerical simulation. P.E Kassabian said in a journal called Foldable Lattice of multi angulated beam connected by cylindrical joints is that the structure consists of a foldable lattice of a multi-angled beam which is connected by cylindrical joints, to which it covering panel or membranes constructed dismountable cover for swimming pool [3]. P. Sri Harshini and his team told about the materials used for retractable roof that are Rain sensor, Humidity sensor, DC motor, Node
MCU has discussed how to use these materials in retractable roof [4]. According to Lawrence he calculated the high strength steel of Reliant stadium which covered 12 acres and he used grade of steel is 65 and for steel materials its grade 65 and he used PTFE for the roof and the steel roof height was 80m from GL this was published in a paper called high strength steel in the long span retractable roof of reliant stadium [5]. Saloni Patidar has explained about the various ways of retractable roof such as,

A retractable roof structure can be moved in various ways.

- Roofing structure with the folding system
- Roofing structure with the sliding system.
- Roofing structure with the rotating system.
- Roofing structure with lifting system.
- Roofing structure with expandable system.[6]

II MATERIALS AND METHODOLOGY COLLECTION OF MATERIALS

1. **Selection of stadium:** M. Chinnaswamy Cricket Stadium Bengaluru also known as Karnataka State Cricket Association stadium. This stadium is an open stadium and has a seating capacity of 40,000.

2. **Material used:** PTFE (Commonly known as Teflon)

   PTFE is chemically inert and its extremely low friction coefficient is very strong & flexible, it is easily washable with no plasticizers. Temperature resistant from -200°C up to +260°C.

3. **Truss Shape:** A Bow Barrel Truss, is commonly called a curved truss (referred from Roger’s stadium, Toronto)

III. METHODOLOGY PROCEDURE FOR CONDUCTION OF EXPERIMENTS

**Calculations of load:**

The loads which are acting on the roof are:

1. Dead Load (IS 875 PART 1)
2. Live Load (IS 875 PART 2)
3. Wind Load (IS 875 PART 3)

**Preliminary calculations of a truss**

- Span = 200m
- Section = ISA200x200x25mm
- Angle = 6 30’
- Spacing for each truss = 10m c/c
- Height of truss above ground level at supports = 30m
- Height of truss above ground level at midspan = 41m
- Thickness of Teflon = 20mm
- Weight of Teflon = 10.59 N/m²
Number of joints= 42  
Number of members= 101  
Number of plates = 0  
Number supports= 2

1. **Dead Load Calculations**

   Self-weight y= -1.000  
   Actual weight of structure= 16.529KN

2. **Live Load Calculations**

   Weight of Teflon= 10.59 N/m²  
   Weight of 1 truss = 54.85 KN  
   Live load acting in y direction= -2.743 KN

3. **Wind Load Calculations**

   According to clause 6.3 from (IS 875 PART 3-2015)

   **DESIGN OF WIND SPEED**

   \[ V_z = V_b \times K_1 \times K_2 \times K_3 \times K_4 \]  
   Where,  
   \( V_b \) = Basic wind speed of Bengaluru (Annex A)  
   \( K_1 \) = Risk coefficient (Table 1)  
   \( K_2 \) = Terrain, Height Factor (Category 4 table 2)  
   \( K_3 \) = Topography factor (clause 6.3.3)  
   \( K_4 \) = Importance factor for the cyclic region (Clause 6.3.4)

   **DESIGN OF WIND PRESSURE**

   \[ P_z = 0.6 \times V_z^2 \, N/m^2 \]

   **Table 1: Calculation of Wind speed and wind pressure**

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Height (m)</th>
<th>Terrain Catg-4 (K2)</th>
<th>Wind Speed (Vz)</th>
<th>Wind Pressure (Pz)</th>
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</table>

   **Design of Wind Force (Table 6 Clause 7.3.3.2)**

   \[ F = C_f \times A_e \times P_d \]  
   \( F \) = Force  
   \( C_f \) = External pressure coefficients  
   \( A_e \) = Area  
   \( P_d \) = Wind pressure
Table 2: Calculation of Wind force

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<tr>
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IV. LOAD BEARING CAPACITY

Fig 1: existing M.Chinnaswamy stadium
Fig 2: half covered retractable roof
Fig 3: Live load acting on the truss

Fig 4: Wind Load acting in X direction

Fig 5: Node displacement readings

Fig 6: 3D model of truss in staad pro

Fig 7: Reading of node displacement
V CONCLUSION

- In this paper our proposed scheme was to design a retractable roof for an existing stadium, to prevent interruption of game, to minimize the impact of weather condition in the stadium and to protect the surface of the ground from rain.
- According to our objectives we have designed many methods in that we have selected a Bow Barrel truss which satisfies all the needs required for the retractable roof and we have done the analysis for this truss and we got to know that the design we proposed is safe.
- Hence the designed structural analysis along the validation of values is safe and satisfactory.

VI. REFERENCES


