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MODELLING AND ANALYSIS OF STADIUM FOR A RETRACTABLE ROOF

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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 E valuation of wind effects on a large span of retractable roof 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-angulated 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 mortar, 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 grade65 and he used PTFE foe 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/m^2

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/m^2

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

$V_Z=V_b*K_1*K_2*K_3*K_4$ Where,

V_b= Basic wind speed of Bengaluru (Annex A)

K1= Risk coefficient (Table 1)

K2= Terrain, Height Factor (Category 4 table 2)

K3=Topography factor (clause 6.3.3)

K4=Importance factor for the cyclic region (Clause 6.3.4)

DESIGN OF WIND PRSSEURE

$P_z= 0.6*Vz^2$ N/m^2

Table 1: Calculation of Wind speed and wind pressure

Sl.no	Height (m)	Terrain Catg-4 (K2)	Wind Speed (Vz)	Wind Pressure (Pz)
1	10	0.8	27.72	461.03
2	15	0.8	27.72	461.03
3	20	0.8	27.72	461.03
4	30	0.97	33.61	677.71
5	35	1.01	34.99	734.98
6	40	1.05	36.38	984.102
7	41	1.056	36.59	803.29

Design of Wind Force (Table 6 Clause 7.3.3.2)

F= Cf * Ae * Pd

F= Force

Cf= External pressure coefficients

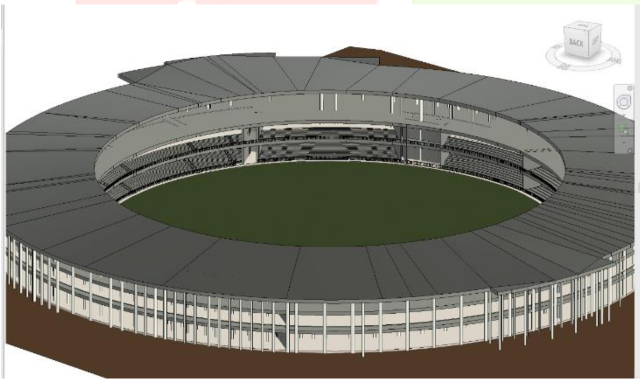
Ae= Area

Pd = Wind pressure

Table 2: Calculation of Wind force.

Sl.no	Height (m)	Force (N/m)	Force (KN/m)
1	10	2074.63	2.074
2	15	2074.63	2.074
3	20	2074.63	2.074
4	30	3049.96	3.049
5	33.5	3237	3.237
6	34.93	3300	3.300
7	35	3307	3.307
8	36.208	3377	3.377
9	37.285	3437	3.437
10	38.303	3490	3.490
11	39.127	3530	3.530
12	39.801	3560	3.560
13	40	3573	3.573
14	40.329	3586	3.586
15	40.700	3600	3.600
16	40.925	3610	3.610
17	41.00	3614	3.614

IV. LOAD BEARING CAPACITY



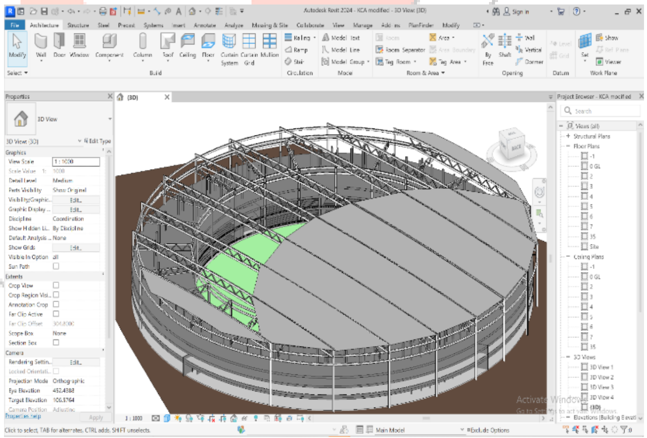
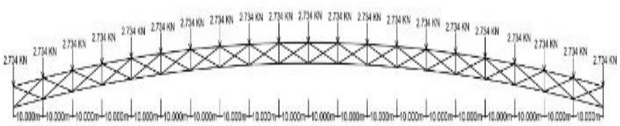


Fig 1: existing M.Chinnaswamy stadium *Fig 2: half covered retractable roof*



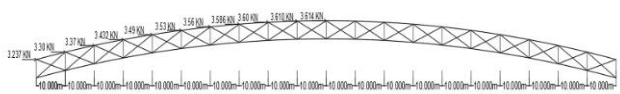


Fig 3: Live load acting on the truss

Fig 4: Wind Load acting in X direction

Node Displacements Cont...

Node	L/C	X (m)	Y (m)	Z (m)	Resultant (m)	rX (rad)	rY (rad)	rZ (rad)
	10:GENERATE	-0.002	-0.005	0.000	0.005	0.00000	0.00000	0.00000
5	1:DL	-0.000	-0.003	0.000	0.003	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.011	0.000	0.011	0.00000	0.00000	0.00000
	3:WL	0.001	-0.006	0.000	0.006	0.00000	0.00000	0.00000
	4:GENERATEI	-0.001	-0.024	0.000	0.024	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.005	0.000	0.005	0.00000	0.00000	0.00000
	6:GENERATEI	-0.001	-0.018	0.000	0.018	0.00000	0.00000	0.00000
	7:GENERATEI	0.002	-0.015	0.000	0.015	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	0.004	0.000	0.004	0.00000	0.00000	0.00000
	9:GENERATEI	0.001	-0.025	0.000	0.025	0.00000	0.00000	0.00000
	10:GENERATE	-0.002	-0.011	0.000	0.011	0.00000	0.00000	0.00000
6	1:DL	-0.000	-0.004	0.000	0.004	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.015	0.000	0.015	0.00000	0.00000	0.00000
	3:WL	0.001	-0.006	0.000	0.006	0.00000	0.00000	0.00000
	4:GENERATEI	-0.000	-0.033	0.000	0.033	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.008	0.000	0.008	0.00000	0.00000	0.00000
	6:GENERATEI	-0.000	-0.025	0.000	0.025	0.00000	0.00000	0.00000
	7:GENERATEI	0.002	-0.017	0.000	0.017	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	0.002	0.000	0.003	0.00000	0.00000	0.00000
	9:GENERATEI	0.001	-0.032	0.000	0.032	0.00000	0.00000	0.00000
	10:GENERATE	-0.002	-0.018	0.000	0.018	0.00000	0.00000	0.00000
7	1:DL	-0.000	-0.006	0.000	0.006	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.019	0.000	0.019	0.00000	0.00000	0.00000
	3:WL	0.001	-0.005	0.000	0.005	0.00000	0.00000	0.00000
	4:GENERATEI	-0.000	-0.041	0.000	0.041	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.009	0.000	0.009	0.00000	0.00000	0.00000
	6:GENERATEI	-0.000	-0.031	0.000	0.031	0.00000	0.00000	0.00000
	7:GENERATEI	0.002	-0.018	0.000	0.018	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	-0.001	0.000	0.002	0.00000	0.00000	0.00000
	9:GENERATEI	0.002	-0.038	0.000	0.038	0.00000	0.00000	0.00000
	10:GENERATE	-0.002	-0.025	0.000	0.025	0.00000	0.00000	0.00000
8	1:DL	-0.000	-0.007	0.000	0.007	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.022	0.000	0.022	0.00000	0.00000	0.00000
	3:WL	0.001	-0.004	0.000	0.004	0.00000	0.00000	0.00000
	4:GENERATEI	-0.000	-0.048	0.000	0.048	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.011	0.000	0.011	0.00000	0.00000	0.00000
	6:GENERATEI	-0.000	-0.037	0.000	0.037	0.00000	0.00000	0.00000
	7:GENERATEI	0.002	-0.018	0.000	0.018	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	-0.004	0.000	0.004	0.00000	0.00000	0.00000

Fig 5: Node displacement readings

Reactions

Node	L/C	Horizontal FX (kN)	Vertical FY (kN)	Horizontal FZ (kN)	Moment MX (kNm)	MY (kNm)	MZ (kNm)
1	1:DL	9.119	1.858	0.000	0.000	0.000	0.000
	2:LL	30.428	6.475	0.000	0.000	0.000	0.000
	3:WL	-4.697	-0.365	0.000	0.000	0.000	0.000
	4:GENERATEI	67.230	14.166	0.000	0.000	0.000	0.000
	5:GENERATEI	15.502	3.158	0.000	0.000	0.000	0.000
	6:GENERATEI	51.411	10.833	0.000	0.000	0.000	0.000
	7:GENERATEI	7.517	2.537	0.000	0.000	0.000	0.000
	8:GENERATEI	23.487	3.780	0.000	0.000	0.000	0.000
	9:GENERATEI	45.305	10.357	0.000	0.000	0.000	0.000
	10:GENERATE	57.518	11.308	0.000	0.000	0.000	0.000
21	1:DL	-9.119	1.858	0.000	0.000	0.000	0.000
	2:LL	-30.428	6.475	0.000	0.000	0.000	0.000
	3:WL	-3.921	0.365	0.000	0.000	0.000	0.000
	4:GENERATEI	-67.230	14.166	0.000	0.000	0.000	0.000
	5:GENERATEI	-15.502	3.159	0.000	0.000	0.000	0.000
	6:GENERATEI	-51.411	10.833	0.000	0.000	0.000	0.000
	7:GENERATEI	-22.168	3.780	0.000	0.000	0.000	0.000
	8:GENERATEI	-8.837	2.537	0.000	0.000	0.000	0.000
	9:GENERATEI	-56.508	11.308	0.000	0.000	0.000	0.000
	10:GENERATE	-46.314	10.357	0.000	0.000	0.000	0.000

Fig 5: Reactions of truss

Node Displacements

Node	L/C	X (m)	Y (m)	Z (m)	Resultant (m)	rX (rad)	rY (rad)	rZ (rad)
1	1:DL	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	2:LL	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	3:WL	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	4:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	5:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	6:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	7:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	8:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	9:GENERATEI	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
	10:GENERATE	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000
2	1:DL	-0.000	-0.000	0.000	0.000	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.001	0.000	0.001	0.00000	0.00000	0.00000
	3:WL	0.000	-0.002	0.000	0.002	0.00000	0.00000	0.00000
	4:GENERATEI	-0.001	-0.002	0.000	0.002	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.000	0.000	0.001	0.00000	0.00000	0.00000
	6:GENERATEI	-0.001	-0.002	0.000	0.002	0.00000	0.00000	0.00000
	7:GENERATEI	0.001	-0.004	0.000	0.004	0.00000	0.00000	0.00000
	8:GENERATEI	-0.001	0.003	0.000	0.003	0.00000	0.00000	0.00000
	9:GENERATEI	-0.000	-0.004	0.000	0.004	0.00000	0.00000	0.00000
	10:GENERATE	-0.001	0.001	0.000	0.002	0.00000	0.00000	0.00000
3	1:DL	-0.000	-0.001	0.000	0.001	0.00000	0.00000	0.00000
	2:LL	-0.001	-0.003	0.000	0.003	0.00000	0.00000	0.00000
	3:WL	0.001	-0.004	0.000	0.004	0.00000	0.00000	0.00000
	4:GENERATEI	-0.001	-0.007	0.000	0.008	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.002	0.000	0.002	0.00000	0.00000	0.00000
	6:GENERATEI	-0.001	-0.006	0.000	0.006	0.00000	0.00000	0.00000
	7:GENERATEI	0.001	-0.008	0.000	0.008	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	0.005	0.000	0.005	0.00000	0.00000	0.00000
	9:GENERATEI	0.000	-0.011	0.000	0.011	0.00000	0.00000	0.00000
	10:GENERATE	-0.002	-0.001	0.000	0.002	0.00000	0.00000	0.00000
4	1:DL	-0.000	-0.002	0.000	0.002	0.00000	0.00000	0.00000
	2:LL	-0.000	-0.007	0.000	0.007	0.00000	0.00000	0.00000
	3:WL	0.001	-0.005	0.000	0.005	0.00000	0.00000	0.00000
	4:GENERATEI	-0.001	-0.015	0.000	0.015	0.00000	0.00000	0.00000
	5:GENERATEI	-0.000	-0.003	0.000	0.003	0.00000	0.00000	0.00000
	6:GENERATEI	-0.001	-0.012	0.000	0.012	0.00000	0.00000	0.00000
	7:GENERATEI	0.001	-0.012	0.000	0.012	0.00000	0.00000	0.00000
	8:GENERATEI	-0.002	0.005	0.000	0.005	0.00000	0.00000	0.00000
	9:GENERATEI	0.000	-0.018	0.000	0.018	0.00000	0.00000	0.00000

Fig 7: Reading of node displacement staad pro

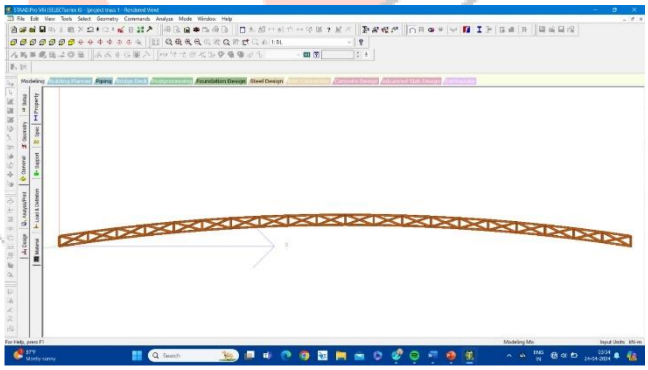


Fig 6: 3D model of truss in

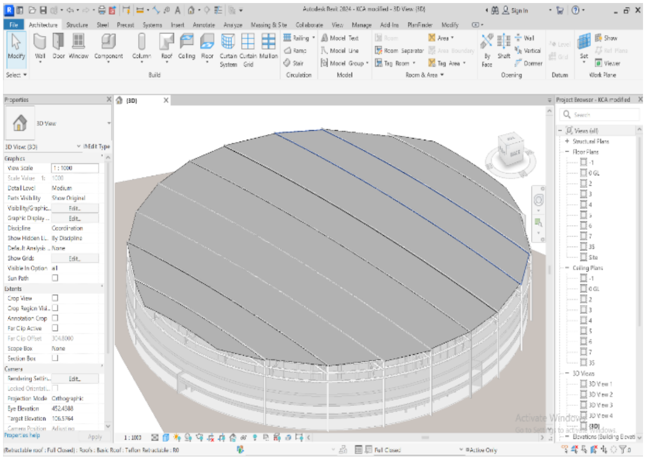


Fig 8: Final model after designing retractable roo

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.

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