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# Planning and Analysis of an Arched Indoor Stadium

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**ABSTRACT**
This paper deals with planning and designing of a multilevel indoor stadium with hanging table tennis court and Olympic standard swimming pool. In order to support the large span the stadium is designed as an arched structure. The materials for the construction are chosen so as to have a minimum carbon di-oxide foot print. Static and earthquake analysis were done by using STAAD.Pro V8i. The paper also does a comparison between arched structure and plane frame structure.
***Keywords*** **–** multilevel indoor stadium, hanging floor, Olympic standard swimming pool

## I. Introduction

In Kerala there is no Olympic standard swimming pools and table tennis courts. The best sports centre in Kerala is Regional Sports Centre Kadavantra, which leads the development of elite sport in Cochin city. The existing swimming pool in RSC is not of Olympic standards. For National Games, Sports Council of India had proposed a new Multipurpose Indoor Stadium to improve the facilities. The newly proposed stadium replaces the existing swimming pool and basketball court there. The multilevel stadium has more relevance in this scenario, because of lack of space for construction. The stadium consists of basement parking facilities, Olympic standard swimming pool, Table tennis room and Residential and other facilities for athletes.

The indoor stadium is designed as a zero energy building. That is the total energy input and output is zero. Also the usage and wastage of energy during construction is minimized. This is very important aspect due to acute energy shortage faced by our country today. The materials for the construction are chosen so as to have a minimum carbon di-oxide foot print.

An Olympic-size swimming pool is the type of swimming pool used in Olympic Games, where the race course is 50m (164 ft) and 25m (82 ft) wide as per FINA specifications. So the total size of the stadium is 76m X 33m .In order to support this large span, it is designed as an arched structure.

## II. Literature Review

As per Kerala Municipal Building rule the building is of Group D occupancy classification (Assembly buildings) [1]. KMBR suggests that the Maximum Permissible Coverage (percentage of plot area) is 40%. Maximum permissible F.A.R without additional fee is 1.50 and Maximum permissible F.A.R with additional fee is 2.50. The maximum height of the building or part thereof shall not exceed twice the width of the street abutting the plot plus twice the width of the yard from the building to the abutting street and this height may further be increased proportionately at the rate of 3 metres for every 50 cms. by which the building or the corresponding portion or floor of the building is set back from the building line. For buildings of group D occupancy classification, off-street- parking spaces for motor cars shall be provided with one parking space for every or fraction of 25 seats of accommodation. The planning, design and installation of lifts shall be in accordance with Part VIII, Building services, Section 5, Lift, Elevators and Escalators in National Building Code of India, 1983[2]. FINA (Federal Internationale de Nation) [3] specifies that the race course of the Olympic standard swimming pool is 50m and width of 25m. A minimum depth of 1.48 yards must be maintained from about 1 yard out from one end of pool to about 6 yards from the opposite wall in pools that use starting blocks. A depth of at least 1.09 yards is required everywhere else in the pool. It should have a minimum of 8 lanes, each of 2.73 yards wide and a buffer of at least 0.22 yards.

## III. Functional planning

The functional planning includes detailed standards and specifications regarding the sporting facilities to be provided in the indoor stadium. The dimensions and specifications are selected according to the Olympic standards. All the required facilities including parking, lift, stair case, toilets, residents, medical room, locker, storage etc are provided.

**Stadium Location**: The stadium replaces existing swimming pool and basket ball court of Regional Sport Center, Kadavantra. The plot area available is 92 cent.

**Safety Requirements**: All parts of the stadium, including entrances, exits, stairways, doors, escape routes, roofs and all public and private area and rooms must comply with the safety standards of the appropriate local authorities. All public passageways corridors stairs, doors and gates must be kept free of any obstructions that could impede the free flow of spectators.

**Parking:** The parking facility for about 100 cars is provided at base level. The driveway is of 5m width. The height of the parking area is 3m.Two lifts with capacity of 15 passengers are provided from the base level.

**Swimming Pool:** The design of swimming pool is according to the Olympic standards. According to Olympic standards the width of the lane should be 2.49m and a buffer of at least 0.20m must be in place on the outside of the first and last lanes. A gallery with a capacity of 700 people is provided

**Table Tennis Court:** Six courts of table tennis are provided at the first floor. This floor can also be used as a conventional center. The play area provided for each table is 14m X 7m. A gallery for 700 people is provided.

As the ground floor consists of swimming pool, columns cannot be provided .hence the table tennis floor is hanged from the arches.

**Residence:** In the second floor rooms for athletes are provided with size about 7m X 4m with attached toilets of size 2.35m X 1.75m.

**Other Facilities:** Entertainment zone, Warm up area, kitchen, cafeteria, locker rooms for players and guests, medical room, pharmacy and storage facilities are provided at top floor.

**Dressing Rooms and Toilets:** Dressing rooms and toilets are provided at each floor on the both sides of the lobby.

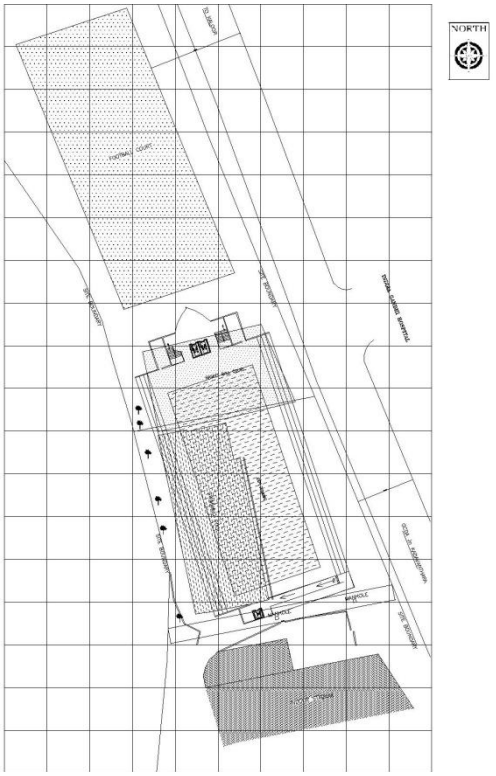


Fig 1 : SITE PLAN

**PLAN**

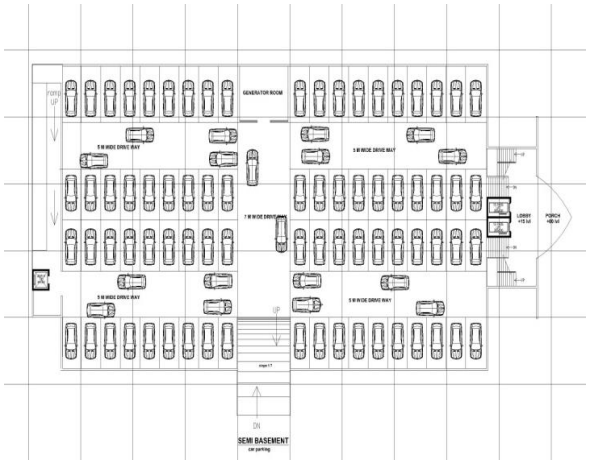


Fig 2. BASEMENT CAR PARKING

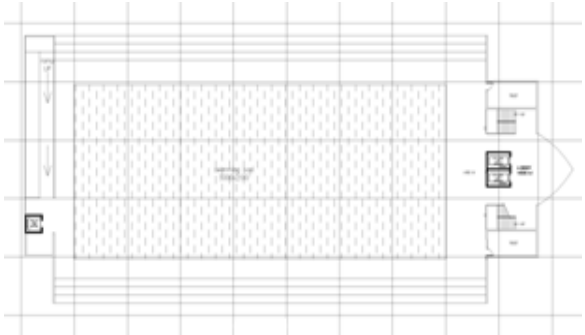

Fig 3. FIRST FLOOR- SWIMMING POOL

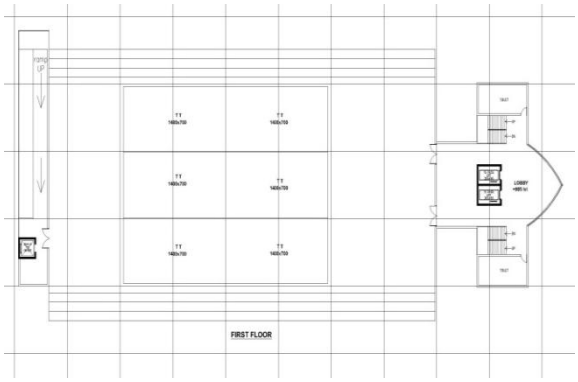


Fig 4.SECOND FLOOR –TABLE TENNIS

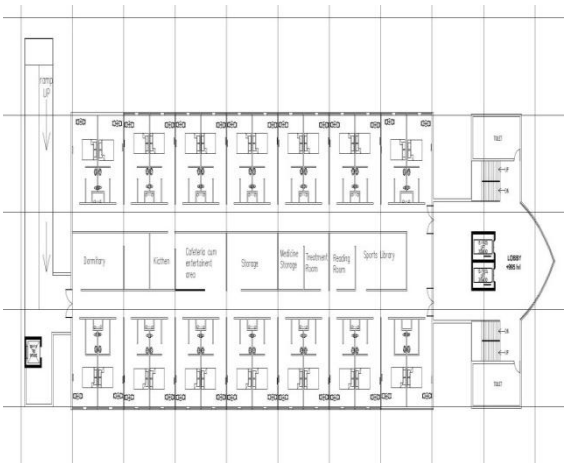

Fig.5 THIRD FLOOR –RESIDENCE

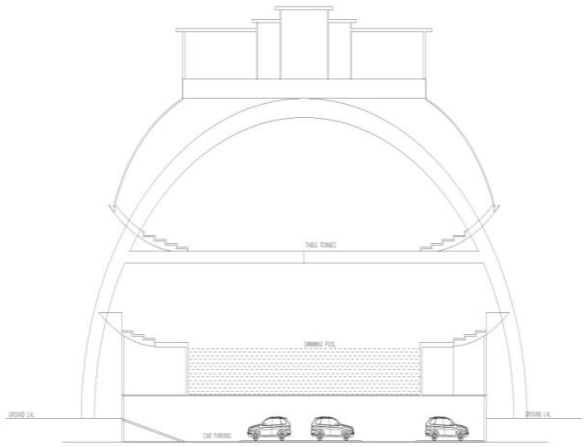

Fig 6. CROSS SECTION

## IV. ANALYSIS AND DESIGN

The structure was analyzed in STAADPro.V8i.

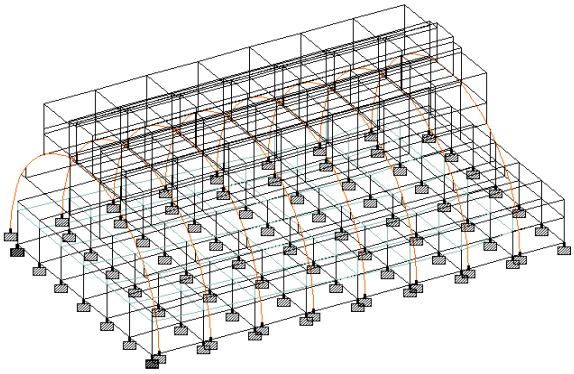

Fig 7. structural frame of the central portion

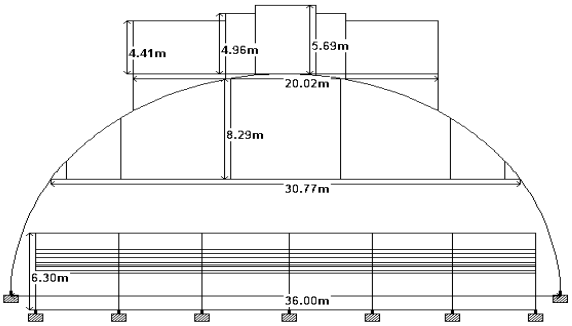


Fig 8. Section along yz plane

The fig shows the analysis model in staad pro. An arch is used to ha ng the lower table tennis floor and to support the upper residential floor. Self weight loads, floor live loads, wind loads, and earthquake loads were used in the analysis. The member sizes were fixed approximately using IS 456. The building is supported on piles all around as it is situated on soft soil and hence fixed supports were provided all around. The analysis results are shown below

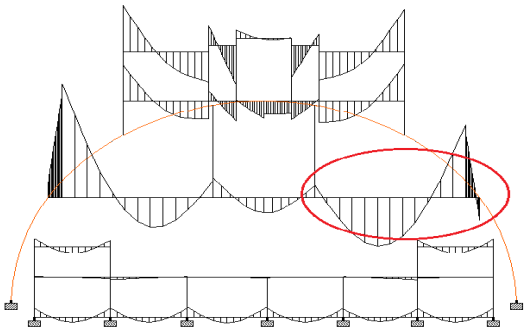

Fig 9. Bending moment diagram.

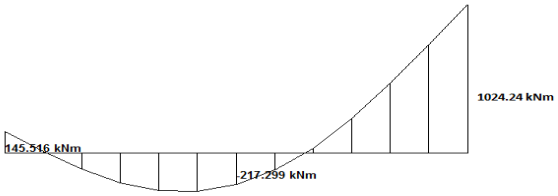


Fig 10.Beam with max bending moment

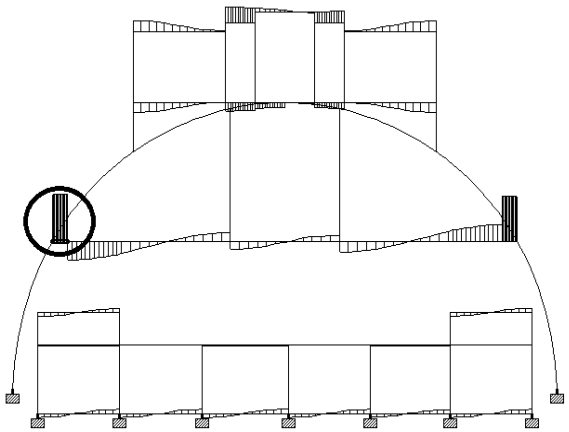

Fig 12. Shear force diagram.

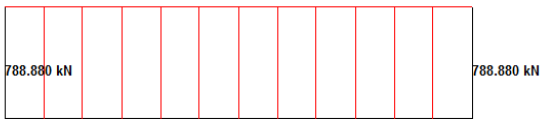


Fig 13.Beam with max Shear force

| | Beam | Node | Fx kN | Fy kN | Fz kN | Mx kNm | My kNm | Mz kNm |
|---|---|---|---|---|---|---|---|---|
| Max Fx | 10649 | 8274 | **3798.98** | 2.483 | 108.558 | -1.087 | 524.136 | -0.308 |
| Min Fx | 50262 | 5016 | **-1708.23** | 312.16 | -0.268 | 0.002 | 0.838 | 540.713 |
| Max Fy | 50246 | 6013 | -1399.46 | **788.88** | -4.088 | 0.031 | 1.044 | 907.558 |
| Min Fy | 50278 | 8293 | -1406.63 | **-801.69** | -0.381 | -0.003 | -0.262 | 108.188 |
| Max Fz | 10957 | 8295 | 677.685 | -24.212 | **1082.31** | -0.660 | -505.247 | -16.098 |
| Min Fz | 10958 | 8298 | 733.588 | -24.409 | **-1059.85** | -1.398 | 526.624 | -16.999 |
| Max Mx | 10677 | 8312 | 1126.71 | 38.354 | 290.899 | **95.501** | 577.023 | 11.985 |
| Min Mx | 10674 | 8306 | 1253.64 | -33.209 | -295.679 | **-88.48** | 658.133 | -7.331 |
| Max My | 10651 | 8284 | 2328.97 | -0.255 | -700.184 | -1.762 | **1581.62** | 1.731 |
| Min My | 10655 | 8290 | 2933.09 | 0.114 | -105.934 | -1.542 | **-860.042** | 0.207 |
| Max Mz | 5016 | 6023 | -1512.05 | -314.52 | 0.061 | -0.001 | 0.224 | **1024.817** |
| Min Mz | 50256 | 8258 | -1670.97 | -350.46 | -0.122 | 0.001 | 0.095 | **-409.743** |

Table 1 summary of bending moment and shear forces

| | Node | Horizontal X mm | Vertical Y mm | Horizontal Z mm | Resultant mm |
|---|---|---|---|---|---|
| Max X | 50170 | **11.889** | -32.459 | 29.495 | 45.441 |
| Min X | 6003 | **-2.242** | -36.278 | 29.657 | 46.911 |
| Max Y | 8290 | 0.068 | **23.772** | 62.053 | 66.451 |
| Min Y | 8296 | 0.057 | **-54.045** | 38.623 | 66.428 |
| Max Z | 8273 | 0.044 | 23.731 | **62.420** | 66.779 |
| Min Z | 8287 | 0.006 | 5.517 | **-19.180** | 19.958 |
| Max rX | 50165 | -0.423 | -41.361 | 28.994 | 50.513 |
| Min rX | 8298 | 0.077 | -33.516 | 40.113 | 52.272 |
| Max rY | 50170 | 11.684 | -24.612 | -0.908 | 27.260 |
| Min rY | 50169 | 11.449 | -16.740 | 31.333 | 37.324 |
| Max rZ | 8336 | 0.177 | -28.303 | 35.183 | 45.155 |
| Min rZ | 6003 | -2.242 | -36.278 | 29.657 | 46.911 |
| Max Rs | 8273 | 0.044 | 23.731 | 62.420 | **66.779** |

Table 2 summary of displacements

The above diagrams shows the bending moments and the shear forces in the middle section were the moments and forces were found to be maximum. It shows us that the lower structure is very stable even in earthquake conditions. And that the arched part is the vulnerable part of the structure.

The highest moments appear in the beams that transfer the load to the arches. Designs of the corresponding beams are also included.

Additionally we also carried out the same analysis using a plane frame replacing the arch and found that the moments and force appearing in the arches were significantly lower than the same in the plane frame under similar loading conditions. The results obtained are as follows.

| | **Max. bending moment** | **Max. shear force** |
|---|---|---|
| **Arched structure** | **1024.92 kNm** | **788.89 kN** |
| **Plane frame** | **6659.73 kNm** | **1112.64 kN** |

**Table 3. Comparison of bending and shear forces on arch and plane frame**

## V. CONCLUSION

Various load combinations as per IS code were used, considering wind load as the major apart from other loads. The structure is stable under various load combinations. This paper concludes that the moments and forces appearing in the arches were significantly lower than in case of plane frame under similar loading conditions. Also the paper shows that for long spans arched structures are considerably cost effective than plane frame structures.

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