Comparative Dynamic Analysis of Stadium Roof Structures with Varying Geometrical Forms

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Abstract:

Stadium roof structures are among the most challenging and functionally critical components in modern sports facilities due to their large spans, complex geometrical forms, and vulnerability to dynamic loading. The present study focuses on a comparative dynamic analysis of stadium roof structures with varying geometrical forms. Tubular roof systems are designed in accordance with IS 801:2005, ensuring code-based compliance in member sizing and detailing. Multiple roof geometries such as dome-shaped, radial truss, and asymmetric configurations are modelled in STAAD-Pro and subjected to dynamic analyses using selected recorded earthquake ground motions. Time-history analysis is employed to capture displacement response, internal member forces, natural frequencies, and modal behaviour. Post-dynamic performance of the structures is evaluated in terms of structural safety, serviceability, and energy dissipation characteristics. Analytical validation through simplified methods is carried out to cross-check and confirm the accuracy of STAAD-Pro results. The comparative findings highlight the influence of roof geometry on dynamic response and provide recommendations for selecting geometrical forms that enhance seismic performance while maintaining structural efficiency.

Keywords: - Nonlinear analysis, Staad-pro, Time history

I. INTRODUCTION

Open roofs are typically seen at smaller athletic venues such as country clubs and universities. Both retractable roof and open roof systems are also used in the construction of commercial greenhouses and garden centers for climate control purposes. Some modern athletic facilities are using affordable, less complex roof systems that resemble retractable roofs in appearance and effect. These roof systems, commonly referred to as open roofs, are constructed with similar materials as retractable roofs. Most open roof companies offer polycarbonate or tempered glass roofs for safer sports play and durability.

A. Objective

1 To design a stadium roof as a tubular structure in accordance with IS801:2005.

2 To perform dynamic analysis for various ground motions using previous earthquake data.

3 To check post dynamic behaviour subjected to specified ground motion of stadium roof for frequency due to el-centro for flat, curved and inclined roof.

II LITERATURE REVIEW

Study On Analysis And Design Of Football Stadium.[1]

THIN NWE AYE:- In this study, the main structural elements of the football stadium are presented, with particular emphasis on the steel roof and its interaction with the underlying reinforced concrete structures. The proposed scheme comprised an ellipse shape plan composed of twelve portions with expansion joints. The building is composed of special moment – resisting framed. Dead loads, live loads, impact loads, wind and seismic loadings data are considered based on UBC 97 (Uniform Building Code). ACI 318-99 code is used for R.C grandstand structure and AISC-LRFD 93 code is used for steel structures which is upper part as elliptical steel roof. Wind velocity is taken as 80 mph in this study.

Stochastic Analysis Of A Stadium Roof From Deterministic Wind Tunnel Measurements [2] N. Blaise Dynamic analyses of structures under buffeting wind loads can be performed in a deterministic (Clough and Penzien, 1997) or stochastic (Preumont, 1994) context, both with a modal approach for computational efficiency reasons. In the first option, the forces are deterministically given, and the uncoupled modal equations of motion are solved either in the time domain with a step by- step method, either in the frequency domain, with Fourier transformation. In the second option, the analysis relies on the determination of the Power Spectral Density (PSD) matrix of the structural response given that of the loading.

Finite Element Analysis of Soccer Stadium under Dynamic Loads [3] NilanjalDiwakirti- Before planning the any structure the site plan and the locations are planned. This help to know what type of designed is required for the structure. The site planning and the locations help is finding the seismic zone of the area and the past history it has been. The football stadium is proposal for Raipur city capital of Chhattisgarh, the city is come under zone II of seismic table, but still the stadium is designed for higher zone. The stadium is designed for the capacity of 14,240 people. The max height of the stadium from ground floor is 12.12 m. the grand stand is the most important part of the stadium which is made up of concrete, over which the truss of 13.9 m is resting. The stadium dimension is 138.81 x 107.22 m; it also has four large exit doors.

III. METHODOLOGY

A Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed.

In order to study the seismic behavior of structures subjected to low, intermediate, and high-frequency content ground motions, dynamic analysis is required. The STAAD Pro software is used to perform linear time history analysis.

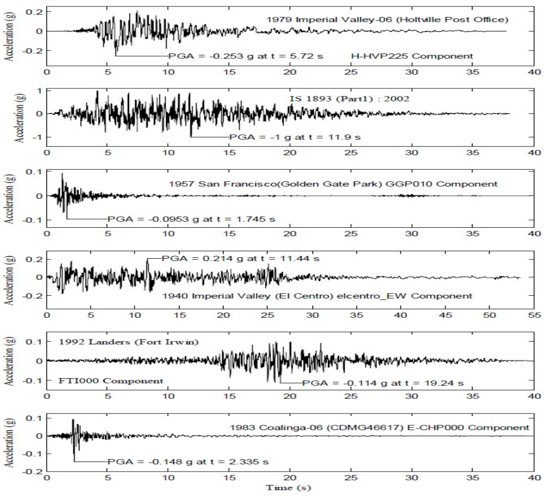

Fig 1.Time History Data for El-Centro

B. Design Criteria

The total design lateral force or design base shear along any principal direction shall be determined by this expression

$V_b = A_h * W$…………………(B)

Were,

Ah = design horizontal seismic coefficient for a structure

W= seismic weight of building

The design horizontal seismic coefficient for a structure Ah is given by

Z is the zone factor given in Table 2 of IS 1893:2002 (part 1) for the maximum considered earthquake (MCE) and service life of a structure in a zone. The factor 2 is to reduce the MCE to the factor for design base earthquake (DBE)

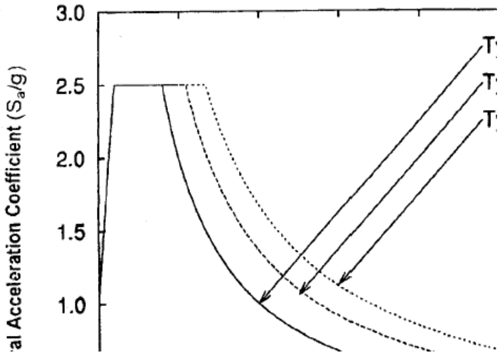

Fig 2 IS Code Spectra From IS 1893:2002 (Part I)

IV FINITE ELEMENT MODEL

A. MODE SHAPES FOR FLAT ROOF

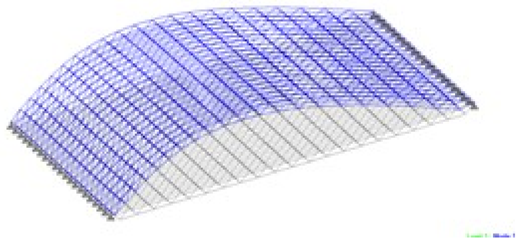

Fig 3 Mode Shape for Flat Roof

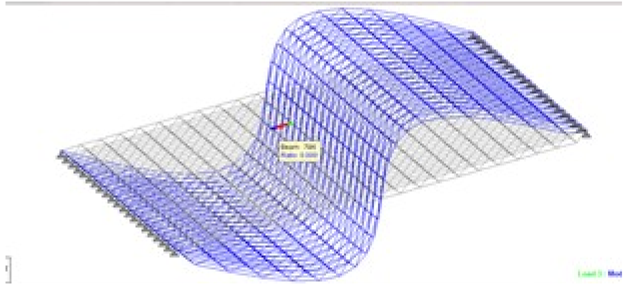

Fig 4 Mode Shape for Flat Roof

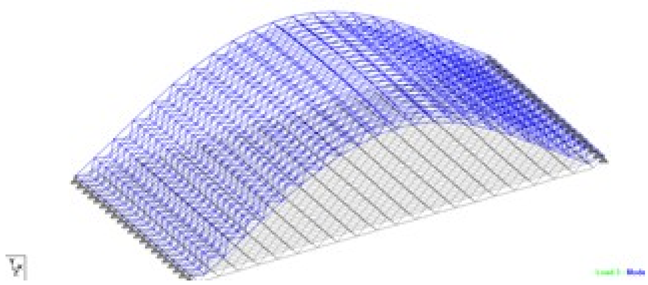

Fig 5 Mode Shape 3 for Flat Roof

B. MODE SHAPES FOR CURVED ROOF

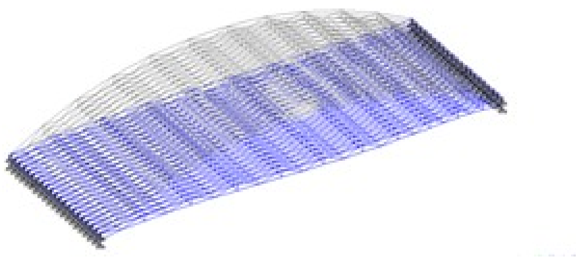

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Fig 6 Mode Shape 1 for Curved Roof

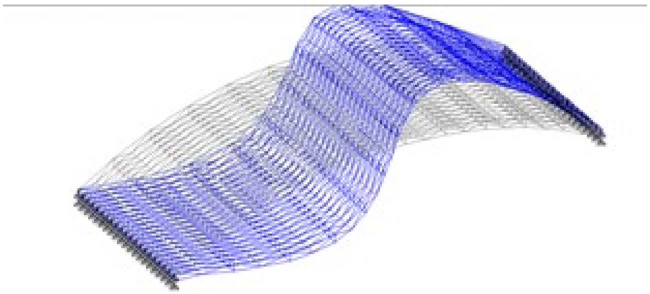

Fig 7 Mode Shape 2 for Curved Roof

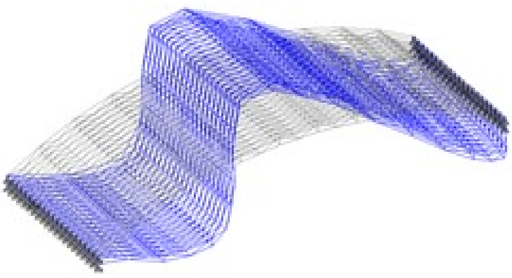

Fig 8 Mode Shape for Curved Roof

C. MODE SHAPES FOR INCLINED ROOF

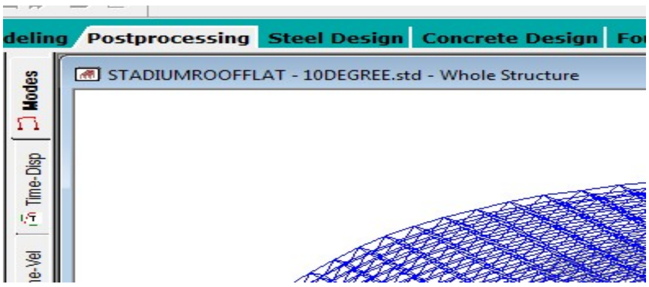

Fig 9 Mode Shape for Inclined Roof

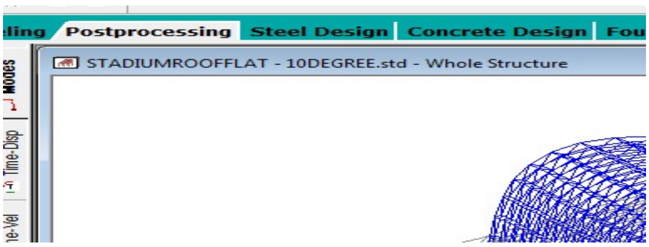

Fig 10 Mode Shape2 for Inclined Roof

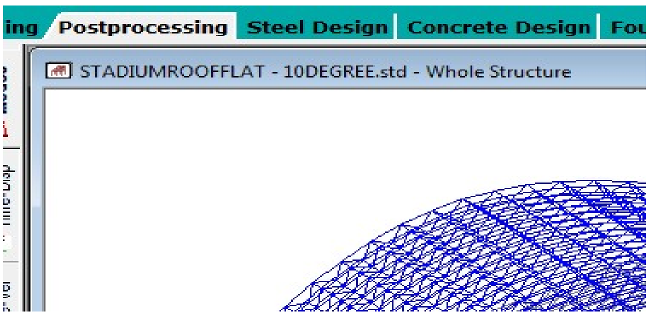

Fig 11 Mode Shape3 for Inclined Roof

V. RESULTS AND DISCUSSION

A. FREQUENCY DUE TO EL-CENTRO FLAT ROOF

Table No. 1 Fequency Due To El-Centro Flat Roof

Mode	Frequency Hz	Period	Participation X %	Participation Y %	Participation Z %
1	0.835	1.197	0	0	84.155
2	1.674	0.597	0	0	0
3	1.984	0.504	0	81.795	0
4	2.003	0.499	0	0	0.011
5	2.52	0.397	0	0	9.125
6	3.234	0.309	0	0.007	0

Above Table shows the frequency for the flat roof in X,Y,Z direction for the different mode shape for EI Centro.

B. FREQUENCY DUE TO EL-CENTRO CURVED ROOF

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	0.473	2.115	0	0	86.282
2	0.94	1.064	0	0	0.006
3	1.42	0.704	0	0	8.685
4	1.899	0.527	0	0	0.028
5	2.376	0.421	0	0	2.489
6	2.622	0.381	19.175	0.086	0

Table No. 2 Frequency Due To El-Centro Curved Roof

Above Table shows the frequency for the curved roof in X,Y,Z direction for the different mode shape for EI Centro.

C. FREQUENCY DUE TO EL-CENTRO INCLIND ROOF

Table No3.Frequency Due To El-Centro Inclined Roof

Mode	Frequency Hz	Period	Participation X %	Participation Y %	Participation Z %
1	0.782	1.279	0	0	84.155
2	1.575	0.635	0	0	0
3	1.984	0.504	0	81.795	0
4	2.002	0.499	0	0	0.011
5	2.388	0.419	0	0	9.125
6	3.218	0.311	0	0.007	0

Above Table shows the frequency for the inclineds roof in X,Y,Z direction for the different mode shape for EI Centro

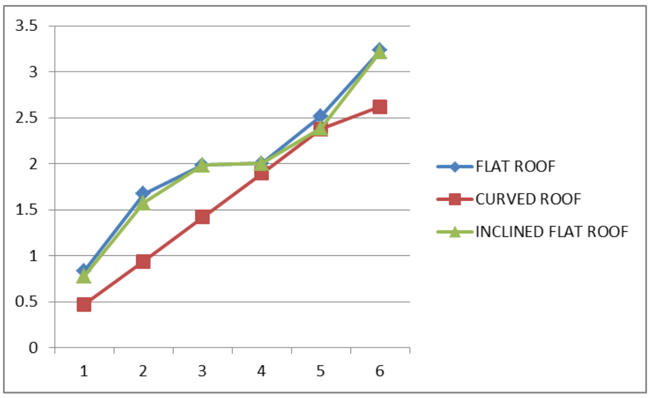

Fig 12 Graphical Representation of Flat Curved and Inclined Roof for Natural Frequency Vs. Mode No

Above graph shows the graphical representation of Flat, curved and inclined roof for natural frequency Vs, Mode

VI. CONCLUSION

1. In This Paper Stadium Roof Is Analyzed for Wind Load and For Time History Analysis. For Wind Load Zone III Is Considered and For Time History Analysis EL-Centro Data Is Used.
2. For Modeling Purpose STADD-PRO Is Used and Following Conclusion Are Obtained: -
   - Natural Frequency Observed More in Curved Roof as Compared To Flat Roof But For Mode No.4 It Was Nearly Same.
   - Time Period Is Less in Flat Roof Hence Better Performance for Curved.
3. Natural Frequency and Mode Shapes Are Nearly Same for Flat Roof and Inclined Roof and gave good results for the curve roof. However, Centre of Mass May Get Shifted.

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