Non Linear Dynamic Analysis of Stadium Roof Using Time History Analysis

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Abstract- *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. In analysing the frames, 28 load combinations are used for all steel members. The grandstand structure is made of reinforced concrete and the roof of structural steel using wide-flanged W-sections and double angles. Structural steel used in the building is A572 Grade 65 steel. Necessary stability checks are carried out.*

I. INTRODUCTION

1. General

- **General**

A stadium roof is a roof system designed to roll back the roof on tracks so that the interior of the facility is open to the outdoors.[1]Retractable roofs are sometimes referred to as operable roofs or retractable skylights. The term operable skylight, while quite similar, refers to a skylight that opens on a hinge, rather than on a track.

Stadium roofs are used in residences, restaurants and bars, swim centres, and other facilities wishing to provide an open-air experience at the push of a button.

- **History**

The United States Patent and Trademark Office (USPTO) shows that David S. Miller, founder of Rollamatic stadium Roofs, filed a patent in August 1963 for a movable and remotely controllable roof section for houses and other types of buildings. [2] As Rollamatic was founded five years earlier, the first installation of a motorized retractable roof must be between 1958 and 1963.

- **Shapes and sizes**

While any shape is possible, common shapes are flat, ridge, hip-ridge, barrel and dome. A residence might incorporate one or more 3' by 5' retractables; a bar or restaurant a retractable roof measuring 20' by 30'; and a meeting hall a 50' by 100' bi-parting-over-stationary

- **Sports venues**

Stadium roofs are generally used in locales where inclement weather, extreme heat, or extreme cold are prevalent during the respective sports seasons, in order to allow for playing of traditionally outdoor sports in more favorable conditions, as well as the comfort of spectators watching games played in such weather. Unlike their predecessors, the domes built primarily during the 1960s, 1970s, and early 1980s, retractable roofs also allow for playing of the same traditionally outdoor sports in outdoor conditions when the weather is more favorable.

- **The first stadium roof**

Figure 1. Civic Arena, built in 1961.

II. AIM AND OBJECTIVES

AIM

Nonlinear dynamic analysis of stadium roof for elcentro earthquake using time history analysis.

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 dyanamic behavior subjected to specified ground motion of stadium roof.
4. To validate the result of STADD-PRO in analytical method.
5. To analyse and compare flat, inclined and curved roof for wind word roof along x-direction and z-direction.

III. METHODOLOGY

1. Design considerations of a stadium roof

For this class discussion divide the class into the three groups representing the Spectators, the Owners/Operators and the Participants

Spectators

- Shading from the sun
- Shelter from the wind and rain
- Unobstructed viewing
- Sense of Identity
- Safety
- Aesthetically pleasing
- Cool and well ventilated

Owners/Operators

- Flexible
- Easy to maintain
- Durable
- Good broadcasting facilities
- Energy Efficient
- Cost Effective

Participants

- Good quality of playing surface
- Good atmosphere
- Floodlighting
- Ventilation

2. Serviceability conditions for stadium Roof

- **Sun exposure**

It is important to model the shadow cast from the roof onto the pitch and stands at different times of the day and year. The main stand of a stadium usually faces east, so that, for afternoon matches, the minimum amount of spectators will have to look into the sun.

Any sport played on a natural grass surfaces, e.g. Football and Rugby, will try to reduce the shading from sunlight on the pitch as this will have a detrimental effect on the grass quality. Completely enclosed stadia cannot, at present, have natural grass pitches but the following experiments have been undertaken;

- Roll-in/Roll-out pitch at Toronto's Skydome. The grass is maintained in the open air then slid into the stadium when needed.
- Grass pitch which can be raised to roof level through the use of jacks, named "Turfdome" and invented in New York by Geiger Engineers, presently un-built.
- Permanent translucent roof fitted with artificial light
- Retractable roofs, allowing sunlight in whilst being able to enclose the entire space if needed.

- **Wind and Air flow**

Circular or elliptical shapes of roofs normally have a claming effect on the air inside the stadium. The comfortable air conditions inside the Don Valley Stadium in the UK are even suggested to enhance the performance of the athletes. However, roofs that are designed to have open gaps at the corners can be beneficial, particularly for grass pitches, as it aids drying out after rain and increases air movement over the grass, enhancing its quality.

- **Flexibility and cost**

The type of roof chosen for a stadium has a massive impact of the flexibility of that venue. To achieve financial viability a stadium needs to bring in revenue during off-season periods and on the days when matches aren't played during the season. Most stadiums achieve this with a generous provision of conference facilities, Health Clubs and even hotels, such as the new development at Twickenham. However some stadiums, such as the Millennium stadium in Cardiff, have retractable roofs allowing it to function in all season and weathers, hosting a range of activities from conventions to opera and major cultural festivals.

- **Design Life/Maintenance**

The design life of different elements of the roof will vary from around 50 years for the load bearing structure to perhaps only a year for some of the finishes, depending on the type and quality. The elements, such as the roof covering and cladding, must be designed for easy replacement and an in depth maintenance strategy will need to be considered during the design stage.

- **Environmentally Sustainable Development (ESD)**

The visual impact that the stadium has on the surrounding area is extremely important to consider at the design stage. Stadiums are inward looking and quite often have tall, imposing “backs” that can be an eyesore at street level outside. Some stadium pitches are actually reduced below ground level to lower the height of the roof structure in order to blend in better. However a stadium that is designed to stand out and make a statement will have an elaborate extravagant roof structure that is hard to miss, such as Wembley.

- **Roof Types**

The form of structure selected for a stadium roof will have the largest impact on the cost, time to construction and obstruction to viewing.

The simplest of structures are Goal Post structures, which comprise of a post at either end of the stand and a single girder spanning the entire length between them that supports the roof. It cheap and used widely in the UK, but is only suitable for rectangular stadia as it cannot form a curve. Cantilever structures are held down by securely fixing one end, leaving the other end to hand unsupported over the stands. This provides unobstructed viewing and can form circles or ellipses, such as the North Stand at Twickenham.

- **Material Selection**

The materials selected for different parts of the roof will be measured against criteria based on required design life, technical aspects and aesthetics.

- **Roof Coverings**

The requirements for a satisfactory roof covering include the need for the material to be lightweight, tough, water-tight, incombustible, aesthetically acceptable, cost-effective and durable. Opaque coverings such as steel or aluminium sheets are commonly used and are cheap and easy to fix. In some instances, where the roof structure is also the covering, lightweight concrete is used but it will become weathered and stained if not treated or finished. Translucent coverings are often rigid plastics, such as PVC or acrylic, which are waterproof, strong and can withstand large deformations without damage. Plastic fabrics can also be used as a non-rigid, transparent roof covering used for the roofing of the Olympic stadium refurbishment in Rome for the 1990 World Cup and can create dramatic shapes if used correctly.

- **Concrete**

Concrete is a very versatile building material and is commonly-used for stadiums as it is cheap, fire-proof and can be cast in any shape. This makes it the only material capable of creating the seating profiles for a stadium but is rarely used for the roofs as it is heavy and unattractive once weathered.

- **Steel**

Steel offers a slender and graceful solution for roofs as it is lighter and more aesthetically pleasing than concrete, so is the obvious choice for roof structures. Also, as the roof sits above the spectators, the required fire-proofing for safety is less, as long as the stadium can be evacuated within a defined time before structural failure or smoke suffocation occurs.

IV. PROBLEM STATEMENT

PREPARATION FOR DESIGN CALCULATION

Material- Steel
Section Size- 0.05m
Location- Pune
Basic Wind Speed- 39m/s
Zone – ш
Soil- Clay
Size- 51.4m × 20m
Height-20m
μ- 0.3
E- 2.5×105 MPa
Two models are compared in this paper subjected to El-centro data
Type-I flat stadium roof
Type-II curved stadium roof

V. DATA FOR TIME HISTORY ANALYSIS

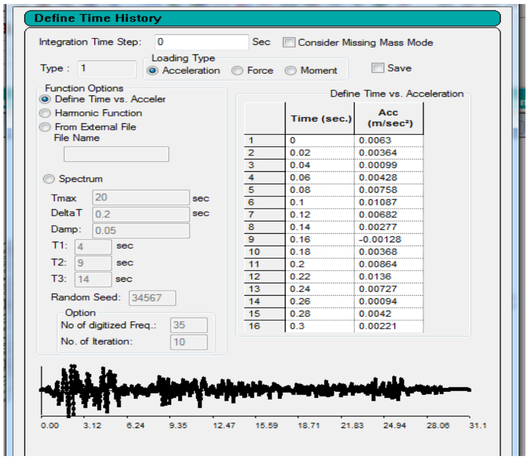

Figure 2.

FINITE ELEMENT ANALYSIS OF PLANE ROOF

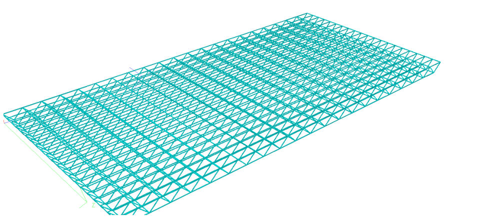

Figure3.

3D VIEW OF FINITE ELEMENT ANALYSIS OF PLANE ROOF

MODE SHAPE

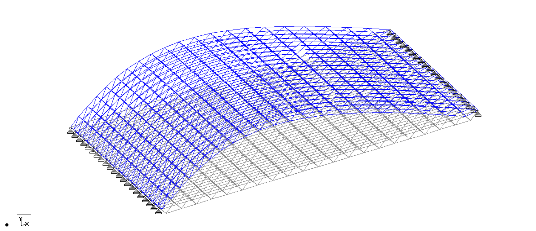

Figure 4 MODE SHAPE 1

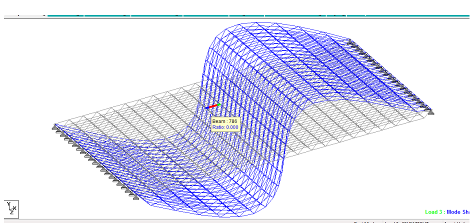

Figure 5. MODE SHAPE 2

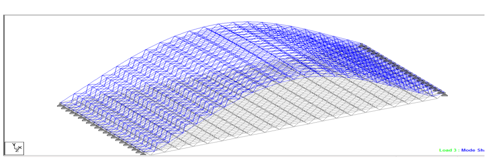

Figure 6. MODE SHAPE 3

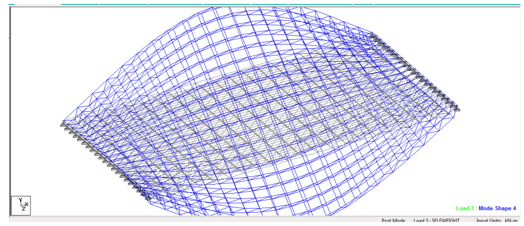

Figure 7. MODE SHAPE 4

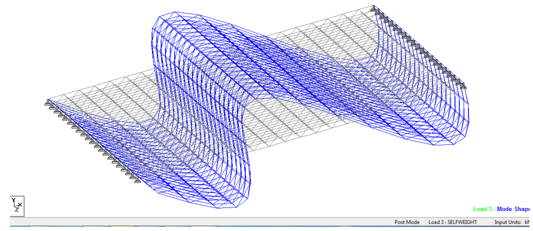

Figure 8. MODE SHAPE 5

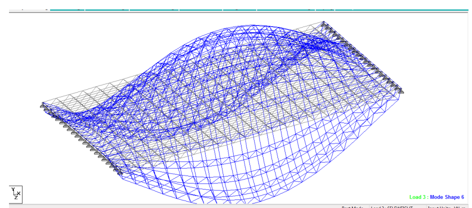

Figure 9. MODE SHAPE 6

FINITE ELEMENT ANALYSIS OF CURVED ROOF

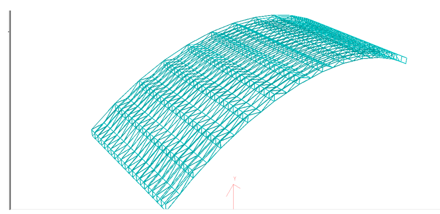

Figure 10.

3D VIEW OF FINITE ELEMENT ANALYSIS OF PLANE ROOF

MODE SHAPE OF FLAT ROOF

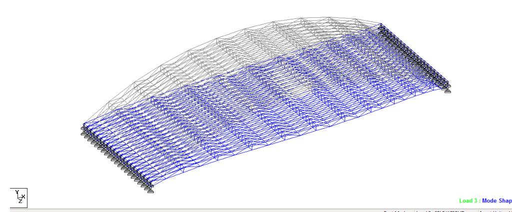

Figure 11. MODE SHAPE 1

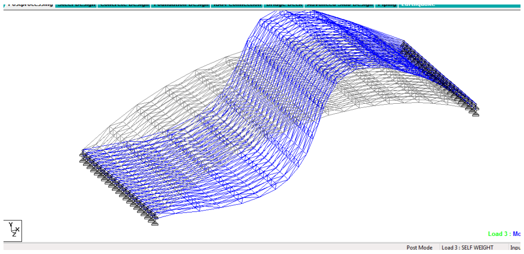

Figure 12. MODE SHAPE 2

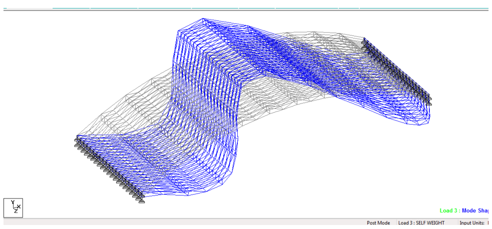

Figure 13. MODE SHAPE 3

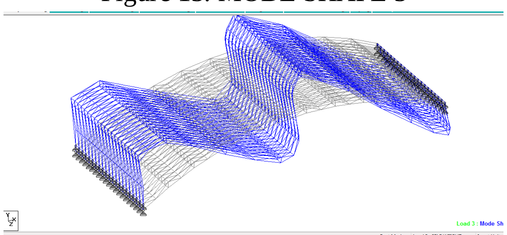

Figure 14. MODE SHAPE 4

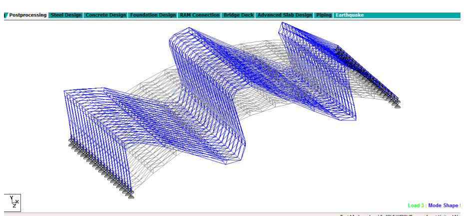

Figure 15. MODE SHAPE 5

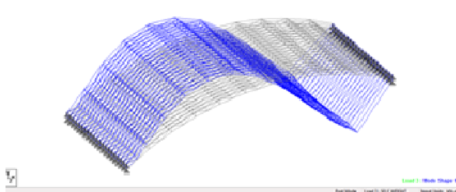

Figure 16.MODE SHAPE 6

FINITE ELEMENT ANALYSIS OF INCLINED ROOF

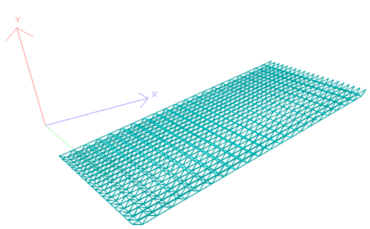

Figure17.

MODE SHAPE OF CURVED ROOF

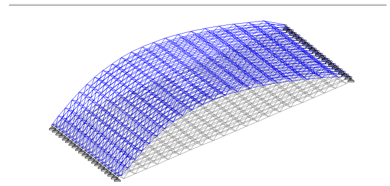

Figure18. MODE SHAPE 1

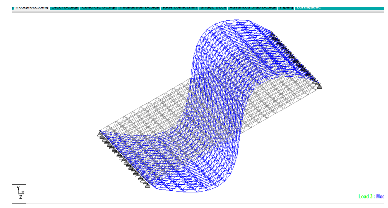

Figure 19. MODE SHAPE 2

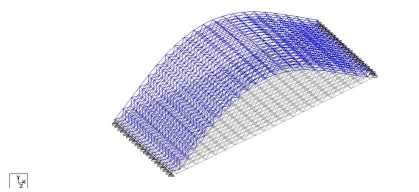

Figure 20. MODE SHAPE 3

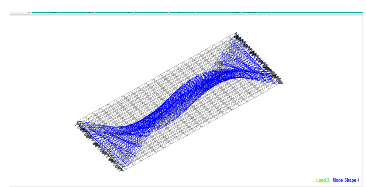

Figure 21. MODE SHAPE 4

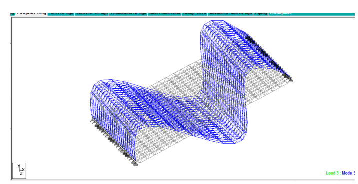

Figure 22. MODE SHAPE 5

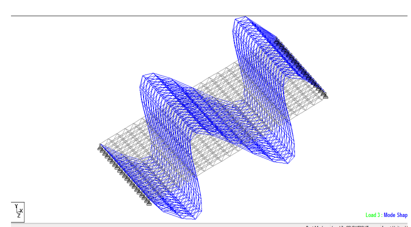

Figure 23. MODE SHAPE 6

VI. RESULTS AND DISCUSSIONS

In this chapter comparison of flat roof ,curved roof and inclined roof is compared for 6 mode shapes for natural frequency and time period

TIME PERIOD AND NATURAL FREQUENCY OF FLAT ROOF

Table 1.

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

TIME PERIOD AND NATURAL FREQUENCY OF CURVED ROOF

Table 2.

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

TIME PERIOD AND NATURAL FREQUENCY OF CURVED ROOF

Table 3.

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

GRAPHICAL REPRESENTATION OF TIME Vs NATURAL FREQUENCY

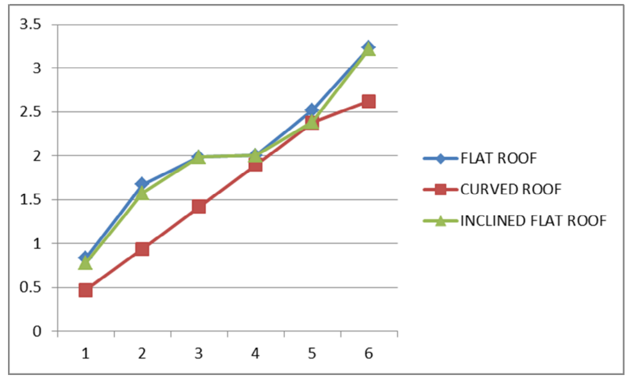

Figure 24.

RESULT OF TIME DISPLACEMENT FOR FLAT, INCLINED AND CURVED ROOF

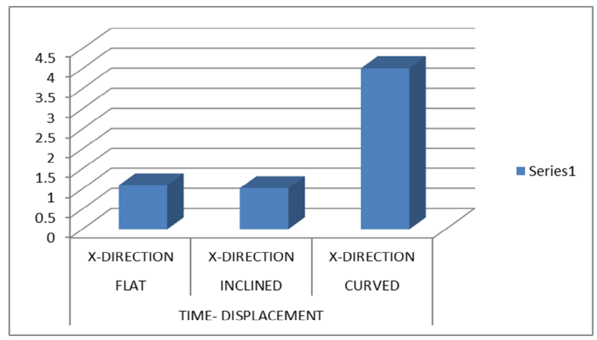

Figure 25.

RESULT OF TIME VELOCITY FOR FLAT, INCLINED AND CURVED ROOF

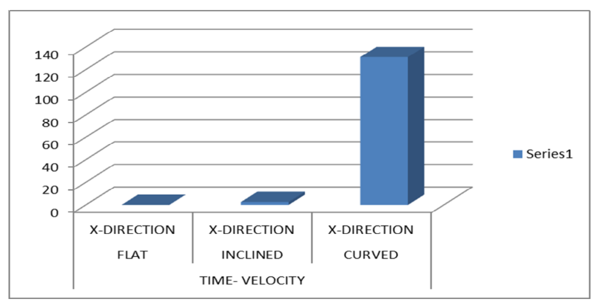

Figure 26.

RESULT OF TIME ACCELARATION FOR FLAT, INCLINED AND CURVED ROOF

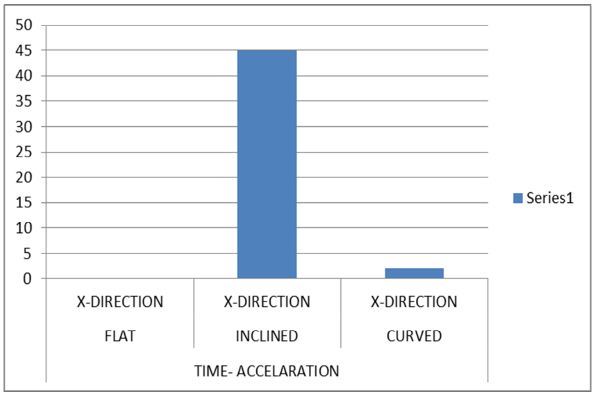

Figure 27.

VII. CONCLUSION

1. For modeling purpose STADD-PRO is used and following conclusion are obtained:-
   a. Natural frequency observed more in flat roof as compared to curved roof but for mode no.4 it was nearly same.
   b. Time period is less in flat slab hence better performance for dynamic load.
2. The Natural frequency, time period, and mode shapes are nearly same for flat roof and inclined roof. However centre of mass may get shifted.

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