PERFORMANCE BASED DESIGN OF OUTDOOR STADIUM CONSIDERING PUSH OVER ANALYSIS FOR DIFFERENT ROOF STRUCTURAL ARRANGMENTS

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ABSTRACT

Pushover analysis is now a days widely used for earthquake response predication of building structures under severe earthquakes at different locations. It needs be studied whether it is applicable for complex large-span steel structures or not. In this paper, pushover analysis of outdoor cricket stadium situated in Rajkot is introduced. Further its push over analysis results are interpreted and concluded for understanding behavior of seismic forces on different structural confurgation of the cantiliver roof structure of outdoor stadium.

Key words — Pushover analysis, Earthquake response, Outdoor stadium

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1 INTRODUCTION TO PERFORMANCE BASED DESIGN

This paper describes a simple computer-based push-over analysis technique for performance-based design of structure. While conventional limit-state design is typically a two-level design approach having concern for the service operational and ultimate-strength limit states for a building, performance-based design can be viewed as a multi-level design approach that additionally has explicit concern for the performance of a building at intermediate limit states related to such issues as occupancy and life-safety standards. With introduction of the performance-based design, there is a need to develop corresponding analysis tools and do time consuming analysis like nonlinear dynamic analysis. Nonlinear static (push-over) analysis is rapidly used as an attractive choice in this regard because of its simplicity and ability to identify component and system-level deformation demands with accuracy comparable to dynamic analysis.

Nonlinear static pushover analysis is an incremental iterative method which gives the base shear versus roof displacement relationship. It is suggested to employ either of two types of load patterns. One is proportional to the fundamental mode. While the other is the uniformly distributed load pattern proportional to the story mass. Other adaptive load patterns based on reliable studies are also allowed. Besides, a 100% dead load plus no less than a 25live load are applied prior to the lateral load in the nonlinear pushover analysis. The monitoring point of pushover analysis is the mass center of the roof story including the penthouse.The end point of the capacity curve corresponds to an ultimate or failure state which is identified when the structure loses stability, or 80% of the elements reach their deformation limit, or more than 20% (maximum or effective) of the base shear strength was reduced after yielding, whichever is critical.

2 NSPS IN EARTHQUAKE ENGINEERING

Nonlinear Static Procedures especially pushover analysis appear as one of the most attractive analysis tool due to their ease of use and also because they provide a simple and effective graphical representation of the structural response in easy step by step procedure, by means of the so called Pushover Curve. The latter relates directly the capacity of the system, usually in terms of base shear, with the response of a significant structural node (control node):such a kind of representation of the overall response allows for a direct idealization of the system as a Single Degree Of Freedom System (SDOFS) that greatly simplifies the design (or assessment) procedure. The majority of the Nonlinear Static procedures follow the same basic principles:

1. A pushover analysis is performed.
2. An equivalent SDOFS, based on the pushover curve, obtained throughout a static pushover analysis, is defined.
3. The maximum global displacement demand is estimated, according to a selected design response spectrum.
4. The SDOFS response and the actual response of the structure are related by means of a shape coefficient, typically identified in the first mode participation factor.
5. Finally, the response parameters, storey drift and forces on each structural member, can be evaluated, knowing the global demand, through the pushover curve (or capacity curve) of the system.

Due to the simplified nature of such methods, they involve many unsolved issues regarding both the capability to capture the dynamic response by means of a pushover analysis as well as the effectiveness of the SDOFS idealization.

All the proposed NSPs differ essentially in the definition of the global displacement demand (step 3) and can be classified in two main groups: equivalent linearization procedures and coefficient methods

Equivalent linearization procedures	Rosenblueth and Herrera (1964) Gülkan and Sozen (1974) Iwan (1980) DDBD, Priestley and Kowalsky (2000) CSM, Freeman (1994) Improved CSM (Chopra and Goel, 1999)
Coefficient methods	Newmark and Hall (1982) Miranda (2000) FEMA 356 (ASCE, 2000) N2-method, Fajfar (1999)

Nonlinear Static Procedures in earthquake engineering

In following discussion, since the work is not focused on the evaluation of a single NSP methodology, only the most updated code procedures, which make use of a pushover-based analysis, are briefly summarized for clarity: i.e. the Eurocode 8 (prENV 1998-1, 1994), FEMA 356 (ASCE, 2000), ATC-40 (ATC, 1996) and FEMA 440 (ATC, 2005).

3 PUSH OVER ANALYSIS OF OUTDOOR STADIUM

Introduction

Stadium consists of mainly roof and main frame. From design perspective, the roof is one of the stadium's most challenging features as it has wide material options , geometric options and structural system options. Steel is one of the materials which is commonly used for large span structures like roof systems. There are many roofs structural systems like cantilever truss, space truss, cable roof which can be possible to cover the structure. Main frame is of either R.C.C. or steel. Main frame consists of seating tiers for spectators and it supports the roof system. For connections, generally welding is used.

Data

For the present study Rajkot Cricket stadium is taken. The objective of the study includes analysis, design and detailing of roof and R.C.C. frame of stadium. This study is carried out with help of "SAP 2000" to obtain accurate analytical results. For roof, 21m long span cantilever roof is designed. Main frame is of R.C.C. consisting of three seating tiers, hotel rooms and gallery.

An attempt is made to design a 21m cantilever roof truss as per IS: 800(1984) and IS: 800 (2007). An alternate system for roof with 4 RHS (rectangular hollow section) sections, 3 RHS sections and pipe sections and channel sections is also considered and these alternatives are then compared in terms of their weight aspects.

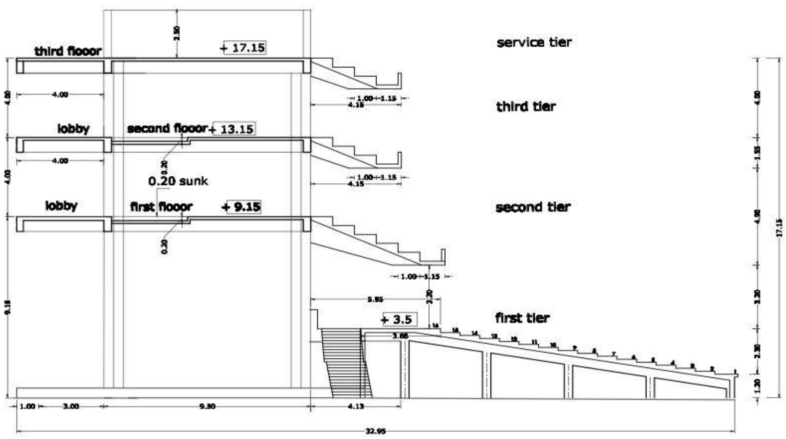


Fig 4 Sectional view of seating deck

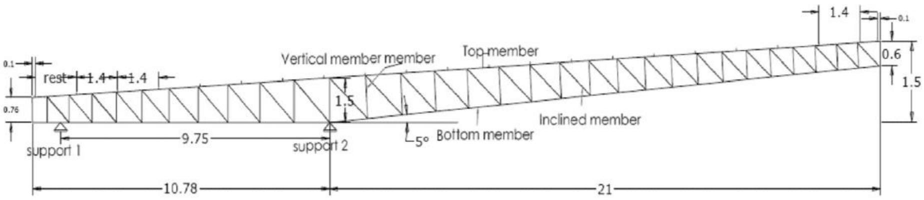


Fig 5 Sectional view of roof truss

Location:	Rajkot
Height of first tier:	9.15 m
Height of second tier:	13.15 m
Height of service tier:	17.15 m
Height of roof:	19.65 m
Seismic zone	III
Basic wind speed	39 m/s
Dimension of column	0.75 x 0.75 m
Length of column	(up to first tier)9.15 m
Length of column	(up to second and service tier)4 m
Depth of foundation	3.0 m
Type of footing:	Isolated
Soil bearing capacity	300 kN/m

LOADS APPLIED

Load on roof truss

Dead load	310N/m
Live load	750N/mm2
Wind load	Downward = 3298.4 N Upward = 8775.07 N

Load on seating deck

Dead Load:	Slab between two frames:	5.25 kN/ m_2
	Cantilever span	5.25 kN/ m_2
	Wall on slab	20.24 kN/m
Live Load:	Slab between two frames	3.5 kN/m
	Live load of seating arrangement	5 kN/m
	On beam	5 kN/m

Earthquake Load:

As per IS : 1893-2002

Earthquake zone: III

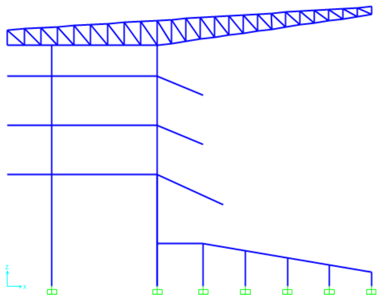
Zone factor= 0.16

Importance factor I= 1.5

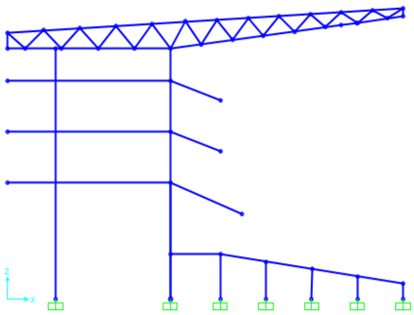
R= 5

Soil strata= hard soil

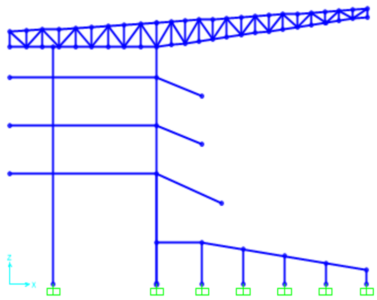
MODELING



CASE 1



CASE 2



CASE 3

CASE 1 STADIUM WITH PRATT TRUSS ROOF ARRANGMENT SYSTEM

CASE 2 STADIUM WITH WARREN TRUSS WITHOUT VERTICAL MEMBERS ROOF ARRANGMENT SYSTEM

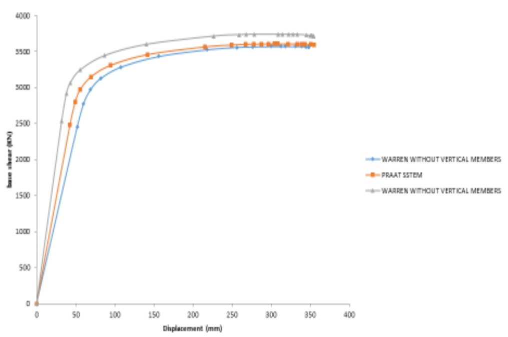
CASE 3 STADIUM WITH WARREN TRUSS WITH VERTICAL MEMBERS ROOF ARRANGMENT SYSTEM

RESULTS

DISPLACEMENTS OF OUTERMOST TRUSS JOINTS (in mm)

	PRATT SYSTEM		WARREN TRUSS W/O VERTICAL MEMBERS		WARREN TRUSS WITH VERTICAL MEMBERS	
	LINEAR	NONLINEAR	LINEAR	NONLINEAR	LINEAR	NONLINEAR
VERTICAL	9.4	137.2	11.3	149.9	7.9	106.2
HORIZONTAL	5.9	92.6	6.7	101.3	4.3	86.4

PUSH OVER CURVE



CONCLUSION.

By referring this study we can conclude the following. In large span roof structures like stadiums by analysing the roof structure we can say that the preferred structural arrangements for cantilever roof in ascending order are Warren truss without vertical members, Pratt system, Warren truss with vertical members. We can also conclude that compared to liner analysis, in nonlinear analysis we have more deformations

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