STRUCTURAL PERFORMANCE OF STADIUM WITH THIN SHELL ROOF STRUCTURE

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ABSTRACT

Structural Engineers and Architects Focused on Shell Structures because of Aesthetic Concerns and their ability to cover large spans also in Extreme condition such as Earthquakes and Hurricanes. In this thesis, Analysis of dome form, Para sine form and Mongue's Surface of Thin Shell Roof Structure in stadium are analysed. Deflection, Moment, Stress variation are analysed based on with Bracing and uniform thickness of shell, Without Bracing and uniform thickness of shell, with bracing and varying thickness of shell and without bracing and varying thickness of shell. For the comparison propose and to observe effect of edge and mesh fineness, dome is modeled as an axi-symmetric model and two axi-symmetric load i.e. self-weight and Seismic Loads are applied to the dome roof in SAP 2000. With Bracing and uniform thickness of slab, Without Bracing and uniform thickness of shell, with bracing and varying thickness of shell and without bracing and varying thickness of shell Roof Structure in Stadium is compared.

KEYWORDS: *Dome, Parabolic Sinusoidal Curve, Bracing Etc.*

INTRODUCTION

The development and construction of thin concrete shell structures dates back to the early 1920's when modern architecture looked for new curvilinear type of free forms of long span, thin, and economical ways to build roof structures that would cover large assembly places, sports arenas, public markets, music halls, and some other similar outdoor and indoor spaces where large number of people could gather under a solid and sound roof structure. Shell structures are very interesting due to their impressive strength-to-weight ratios. They are able to span over large areas, while having an exceptionally less thickness. This is primarily due to their form based structural behavior. The shells earthquake resistance is determined directly by performing a response spectrum analysis, but also indirectly by evaluating the fundamental frequencies of the shell structures. The eigen values and corresponding Eigen modes of a shell are solely dependent on the shell's stiffness and mass distribution, and thus, are independent of loading. Because of difficult to construction, analysis and of shell structure, scope of the shell structure was not come in more practice before 1960's period (1). After some decade development of the computer, numerical method like finite difference method, finite element method etc and development of the new technology of construction, scope of the shell structure start to rise due to aesthetic and structural point of view as impressive strength-to-weight ratios.

We see in shell structure a conventional type of the geometry is used in the field of research and construction example cylindrical shell, conical shell, paraboloid shell, hyperbolic-paraboloid shell etc. with the uniform thickness with or without edge beam. the purpose of this thesis is to use complex geometry like mongue carved surface structure to increase the field of research and to find the best approach geometry for construction of the roof structure keeping good aesthetics appearance and to see /analyse the thin shell roof with the different loading conditions example static, dynamic loading condition etc. Carved surfaces were first studied by the French mathematician-geometer Mongue Gaspard (1746-1818). A carved Mongue surface is a surface composed of orthogonal trajectories of a one-parameter family of planes. Juhanio M. A. was the first researcher who attempts to find the strength of shell in the form of carved Mongue's surface.

Simply Supported Shells (20):- The Term "Simply Supported Shells" describes shells, which terminate at transverse stiffeners that must be integral with the shell. Shell continuous over the stiffeners ate designated as "continuous Shells".

Shells Continuous Over Supports. -The effect of continuity over the supports on stresses in shells is similar to the effect of continuity on stresses in ordinary beams. End restraint of the shell by continuity creates longitudinal stresses at the support, whose magnitude (and sign) are approximately in the same ratio to the longitudinal stresses in the simply supported shell as the end moments in a continuous beam are to the positive (middle span) moment in the same beam, simply supported. In some cases, the values obtained by a rigorous satisfaction of the boundary conditions and those obtained by proportioning the internal forces based on the ratio of end moments to the moment in a simply supported beam are practically identical.

RESEARCH ANALYSIS:

Most of the thin shell roof structure is analysed based on the use of dead load and live load, which might be seen unsafe in Seismic load on structural system. So in this thesis we are going to use varied thickness on the basis of only live load, dead load stress distribution but we are taking in to account as Seismic load. Seismic load in the thin shell structure as roof of the stadium, the roof can bear the Seismic load edge beam of the structure to transfer the stress of one component to the other component or to prevent the edge of the support from punching. Similarly, we can see normally research on simple geometry form so to increase field of research, this thesis aim is to analyse the complex shell roof dynamically and statically by using latest advanced analysis method. The problem induced in the structure as buckling and stress concentration are normally prevented by using bracing which help to transfer stress.

- ✓ Every part of the roof, the stress due to loads induced and the stress is concentrate at the intersection of the roof as edge beam, we should analyse the structure by different method of analysis.
- ✓ Analysis of dome structure, Para sine form structure.

Different tools are used to analysis and of the structure. This first work while starting research is modeling in Sap 2000, Fortran etc. programming for the analysis, validation with manual sectored/discrete form and use of elastic theory, and seismic performance of shell roof Superstructure in Two consecutive direction with validation.

TABLE 1: DETAILING OF STADIUM

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Football Ground		Sine Part		Dome Part	
Length	180.10	Length	80.00	Radius	50.05
Breadth	100.10	Height	21.25	Height	21.41
		Curvature	2.00	slope height	
		Slope Length	34.43		

To create sample example of para sine detailed analysis in FORTRAN

Script of FORTRAN built in program for carved mongue's surface: -

```
NUMBER 0F PACES ALONG AXE X1 - 40   NUMBER OF   PACES ALONG AXE X2 - 60
 KUS=    8127
   E=0.27000E+08   HU= 0.150   ALPHA0= -15.000   BITA0=   .000   H=0.25
   Nnc=  3. an=   0.050 bn=  0.000 Ln=  0.000 -=    0.000
   Noc=  8. ao=   1.000 bn=   1.000 Ln=  16.000 x0 =   .000 Theta=   90.000
      PACES ALONG AXE X1
  1  40     0.375  DLU= 15.00   DLSU= 15.0000
      PACES ALONG AXE X2
  1  60     0.13333  DLU=  8.00   DLSU= 8.00
      CINEMATIC BOUNDARY CONDITION
     0   0   1      0  60   1      0   0   0
    -1  41  42      0  60   1      0   0   0
    40  40   1      0  60   1      0   1   1
     0  40   1      0   0   1      0   0   0
     0  40   1     60  60   1      1   0   1
     0  40   1     61  61   1      0   0   0
    -2   0   0      0   0   0      0   0   0
   No HOLEs  LS=     362
   KN = 7141    LS = 362    NMX =   2616676
 NO ELASTIC FOUNDATION
```

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DISTIBUTED LOAD ON A SURFACE

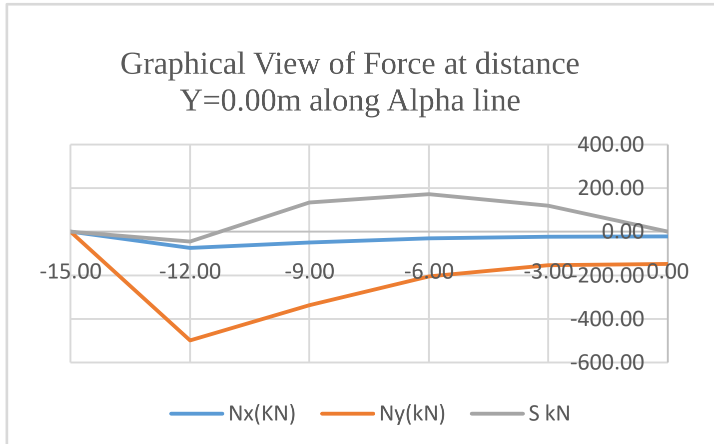
1 0 40 0 60 3 0 -30.00 .00 .00

-2 0 0 0 0 0 0 .00 .00 .00

1 2 0 40 8 0 60 5

TABLE 2 FORCE AT DISTANCE Y= 0M ALONG ALPHA LINE

X (m)	Nx(KN)	Ny(kN)	S kN
-15.00	0.00	0.00	0.00
-12.00	-74.76	-498.40	-45.52
-9.00	-50.49	-336.60	133.20
-6.00	-30.76	-205.10	172.10
-3.00	-23.16	-154.40	119.80
0.00	-22.11	-147.40	0.00



Stadium Roof Structure without Bracing and Uniform Thickness of Shell Model and Deformed Shape in Sap2000

TABLE 3 MODELLING DETAILS OF ROOF STRUCTURE WITHOUT BRACING AND UNIFORM THICKNESS.

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Frame Strucute Part		Sine Part		Dome Part	
Beam (M30)	0.4*0.6	slab (M30)	0.50	slab (M30)	0.50
Column (M30)	1.5*15	Intersection Slab		Sitting Slab	
Ties (M20)	0.3*0.3	slab (M20)	0.13	slab (M30)	0.25
Description			Description		
Grade of Concrete		M20	Grade of Concrete		M30
Weight Per Unit Volume		24.9926 KN/m3	Weight Per Unit Volume		24.9926 KN/m3
Poissions Ratio		0.2	Poissions Ratio		0.2
Modulus of Elasticity		22360680 KN/m2	Modulus of Elasticity		27386128 KN/m2
Coefficient of Thermal		0.0000055 m	Coefficient of Thermal		5.500E-06 m
Shear Modulus		9316950 KN/m2	Shear Modulus		11410887 KN/m2
Specified Compressive concrete strength		20000 KN/m2	Specified Compressive concrete strength		30000 KN/m2
Expected Compressive concrete strength		20000 KN/m2	Expected Compressive concrete strength		30000 KN/m2

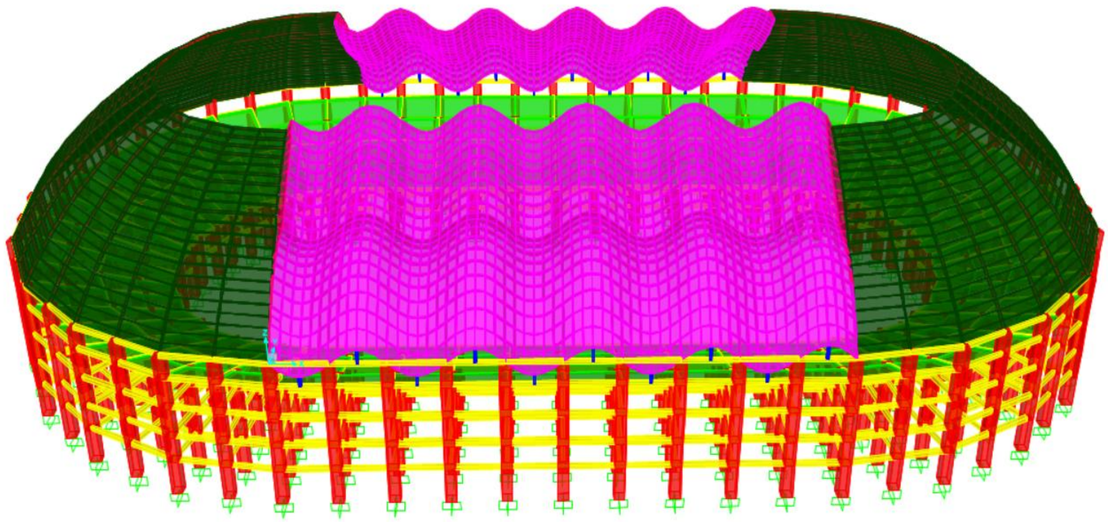


Figure 1 Stadium Roof Structure without Bracing and Uniform Thickness of Shell in Sap 2000

Stadium Roof Structure without Bracing and Varying Thickness of Shell Model and Deformed Shape in Sap 2000

TABLE 4 DETAILS OF STADIUM ROOF STRUCTURE WITHOUT BRACING AND VARYING THICKNESS

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Frame Strucute Part		Sine Part		Dome Part	
Beam (M30)	0.4*0.6	slab (M30)	0.40 to 0.50	slab (M30)	0.40 to 0.50
Column (M30)	1.5*15	Intersection Slab		Sitting Slab	
Ties (M20)	0.3*0.3	slab (M20)	0.13	slab (M30)	0.25
Description			Description		
Grade of Concrete		M20	Grade of Concrete	M30	
Weight Per Unit Volume		24.9926 KN/m3	Weight Per Unit Volume	24.9926 KN/m3	
Poissions Ratio		0.2	Poissions Ratio	0.2	
Modulus of Elasticity		22360680 KN/m2	Modulus of Elasticity	27386128 KN/m2	
Coefficient of Thermal		0.0000055 m	Coefficient of Thermal	5.500E-06 m	
Shear Modulus		9316950 KN/m2	Shear Modulus	11410887 KN/m2	
Specified Compressive concrete strength		20000 KN/m2	Specified Compressive concrete strength	30000 KN/m2	
Expected Compressive concrete strength		20000 KN/m2	Expected Compressive concrete strength	30000 KN/m2	

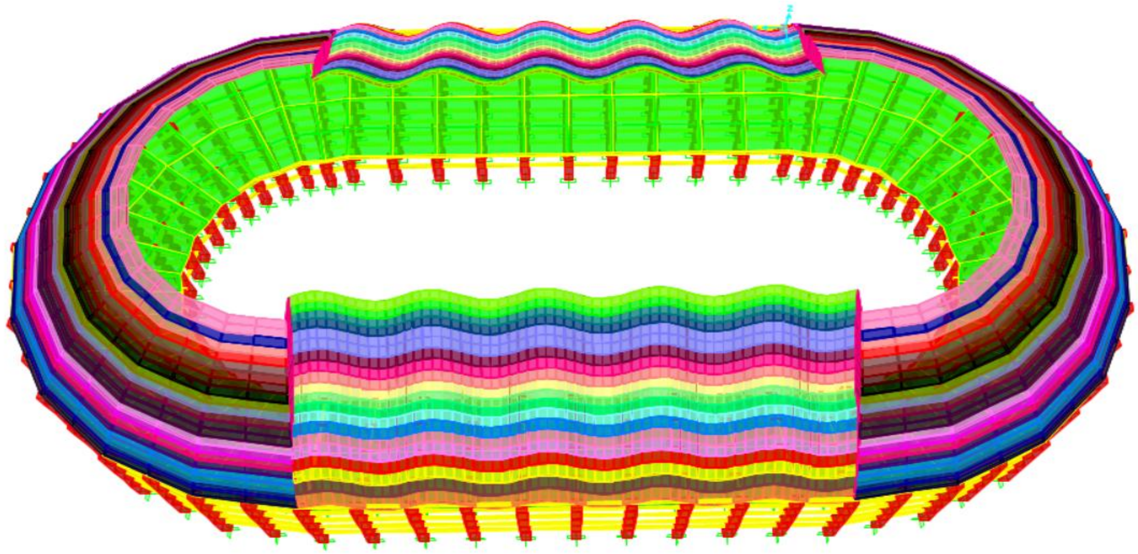


Figure 2 Stadium Roof Structure without Bracing and Varying Thickness of Shell in Sap 2000

Stadium Roof Structure with Bracing and Uniform Thickness of Shell Model and Deformed Shape in Sap 2000.

TABLE 5 MODELLING DETAILS OF STADIUM ROOF STRUCTURE WITH BRACING AND UNIFORM THICKNESS

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Frame Strucute Part		Sine Part		Dome Part	
Beam (M30)	0.4*0.6	Slab (M30)	0.50	Slab (M30)	0.50
Column (M30)	1.5*15	Intersection Slab		Sitting Slab	
Ties (M20)	0.3*0.3	Slab (M20)	0.13	Slab (M30)	0.25
Intersection Beam	0.3*0.3				
Bracing	0.4*0.6				
Description			Description		
Grade of Concrete		M20	Grade of Concrete		M30
Weight Per Unit Volume		24.9926 KN/m3	Weight Per Unit Volume		24.9926 KN/m3
Poissions Ratio		0.2	Poissions Ratio		0.2
Modulus of Elasticity		22360680 KN/m2	Modulus of Elasticity		27386128 KN/m2
Coefficient of Thermal Expansion		0.0000055 m	Coefficient of Thermal		5.500E-06 m
Shear Modulus		9316950 KN/m2	Shear Modulus		11410887 KN/m2
Specified Compressive concrete		20000 KN/m2	Specified Compressive		30000 KN/m2
Expected Compressive concrete		20000 KN/m2	Expected Compressive		30000 KN/m2

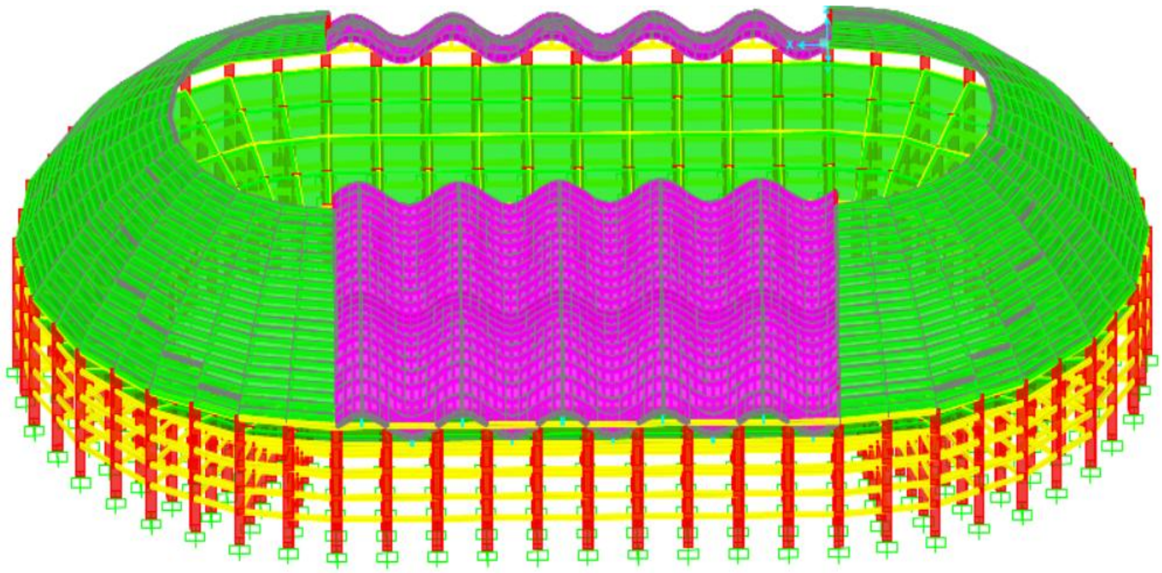


Figure 3 Stadium Roof Structure with Bracing and Uniform Thickness of Shell in Sap

Stadium Roof Structure with Bracing and Uniform Thickness of Shell Model and Deformed Shape in Sap 2000

TABLE 6 MODELLING DETAILS OF STADIUM ROOF STRUCTURE WITH BRACING AND UNIFORM THICKNESS

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Frame Strucute Part		Sine Part		Dome Part	
Beam (M30)	0.4*0.6	Slab (M30)	0.4 to 0.5	Slab (M30)	0.4 to 0.5
Column (M30)	1.5*15	Intersection Slab		Sitting Slab	
Ties (M20)	0.3*0.3	Slab (M20)	0.13	Slab (M30)	0.25
Intersection Beam	0.3*0.3				
Bracing	0.4*0.6				
Description			Description		
Grade of Concrete		M20	Grade of Concrete		M30
Weight Per Unit Volume		24.9926 KN/m3	Weight Per Unit Volume		24.9926 KN/m3
Poissions Ratio		0.2	Poissions Ratio		0.2
Modulus of Elasticity		22360680 KN/m2	Modulus of Elasticity		27386128 KN/m2
Coefficient of Thermal Expansion		0.0000055 m	Coefficient of Thermal		5.500E-06 m
Shear Modulus		9316950 KN/m2	Shear Modulus		11410887 KN/m2
Specified Compressive concrete		20000 KN/m2	Specified Compressive		30000 KN/m2
Expected Compressive concrete		20000 KN/m2	Expected Compressive		30000 KN/m2

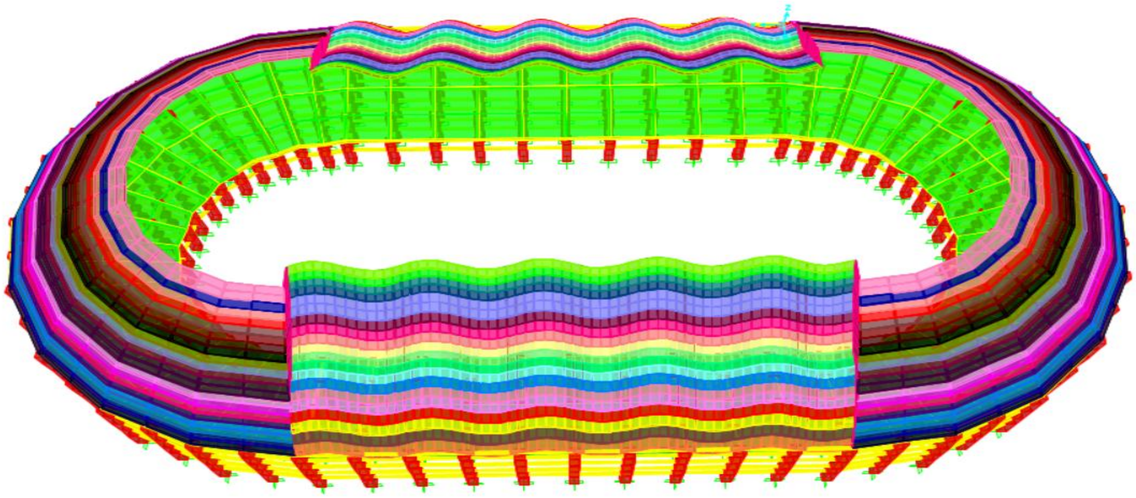


Figure 4 Stadium Roof Structure with Bracing and Varying Thickness of Shell in Sap 2000

Stadium Roof Structure Detailing and View of Different Model in Sap 2000

TABLE 7 MODELLING DETAILS OF STADIUM ROOF STRUCTURE WITH BRACING AT THE TOP ONLY AND UNIFORM THICKNESS

Description	Dimension(m)	Description	Dimension(m)	Description	Dimension(m)
Frame Strucute Part		Sine Part		Dome Part	
Beam (M30)	0.4*0.6	Slab (M30)	0.60	Slab (M30)	0.60
Column (M30)	1.5*15	Intersection Slab		Sitting Slab	
Bracing Beam	0.3*0.6	Slab (M20)	0.13	Slab (M30)	0.25
Intersection Beam	0.3*0.3	Sine Part for varying		Dome Part	
Steel Bracing	ISMC400	Slab (M30)	0.25 to 0.90	Slab (M30)	0.25 to 0.90

Description of Fe345		Description	
Grade of Steel	Fe345	Grade of Concrete	M30
Weight Per Unit Volume	76.9729 KN/m3	Weight Per Unit Volume	24.9926 KN/m3
Poissions Ratio	0.3	Poissions Ratio	0.2
Modulus of Elasticity	$2.1*10^8$ KN/m2	Modulus of Elasticity	27386128 KN/m2
Coefficient of Thermal Expansion	1.170E-05 m	Coefficient of Thermal	5.500E-06 m
Shear Modulus	80769231 KN/m2	Shear Modulus	11410887 KN/m2
Minimum Yield Stress,Fy	345000 KN/m2	Specified Compressive	30000 KN/m2
Minimum Tensile Stress,Fu	450000 KN/m2	Expected Compressive	30000 KN/m2
Description		**Description**	
Grade of Concrete	M20	Stell Channel	ISMC 400
Weight Per Unit Volume	24.9926 KN/m3	Weight Per Meter	49.4 N/m
Poissions Ratio	0.2	Sectional Area	62.93 cm^2
Modulus of Elasticity	22360680 KN/m2	Depth of Section	400 mm
Coefficient of Thermal Expansion	0.0000055 m	Width of flange	100mm
Shear Modulus	9316950 KN/m2	thickness of Flange	15.3 mm
Specified Compressive concrete	20000 KN/m2	Thickness of Web	8.6 mm
Expected Compressive concrete	20000 KN/m2	Center of Gravity	24.2 mm

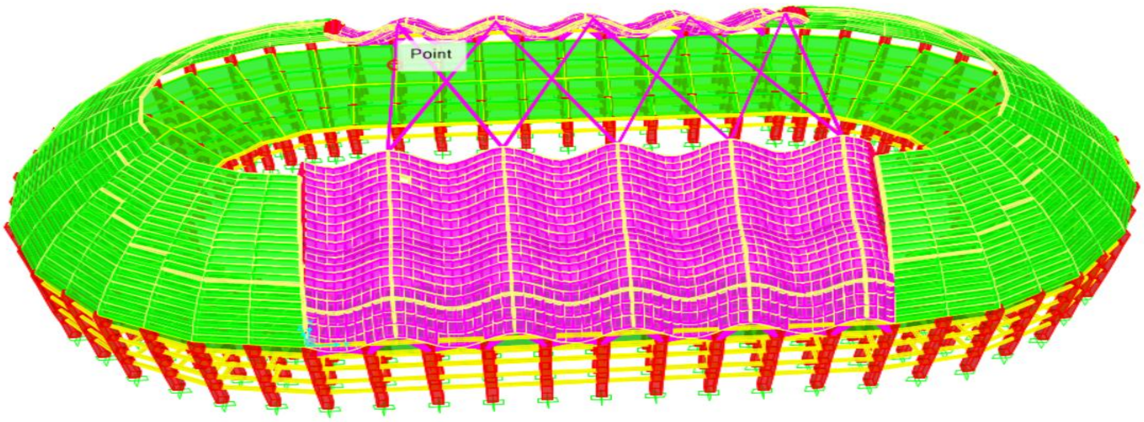


Figure 5 Bracing in roof as well as top of the stadium with Uniform Thickness of RCC Shell in Sap 2000

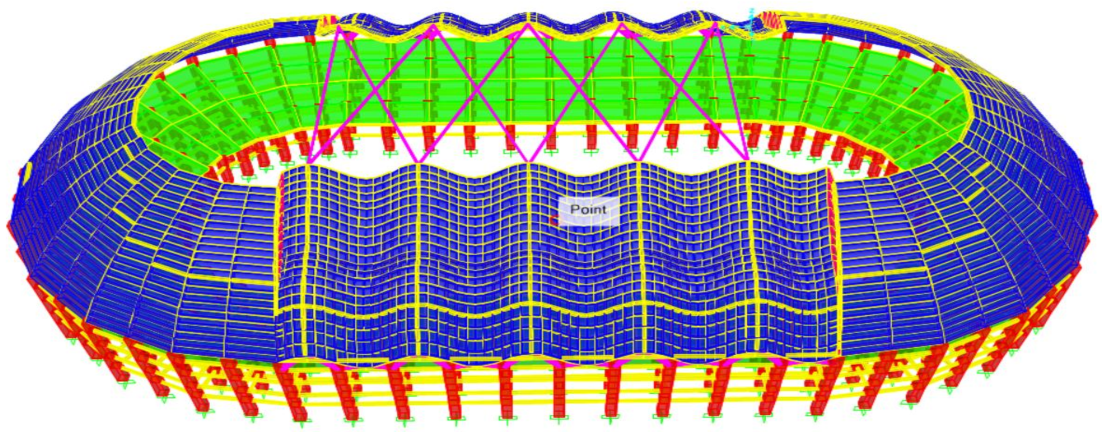


Figure 6: Bracing in roof as well as top of the stadium with Varying Thickness of RCC Shell in Sap 2000

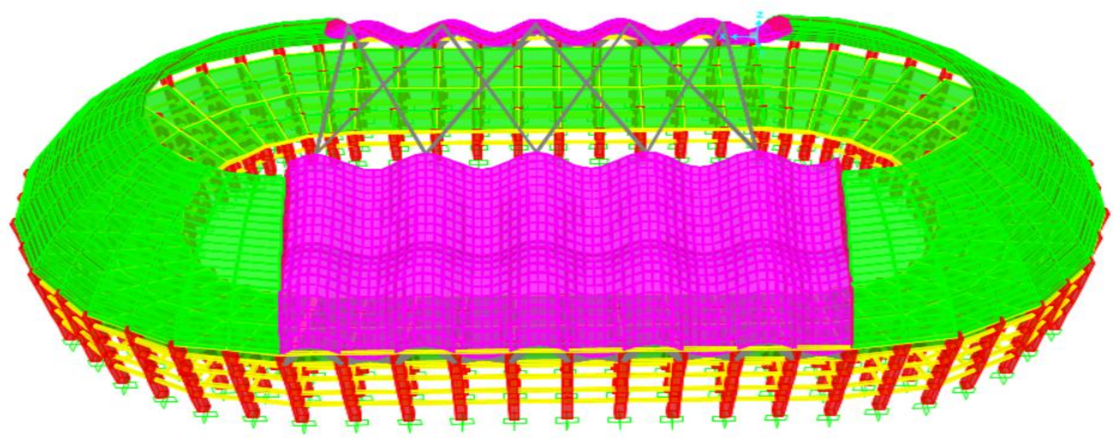


Figure 7 Bracing Only on top of the stadium with uniform Thickness of shell in RCC Sap 2000

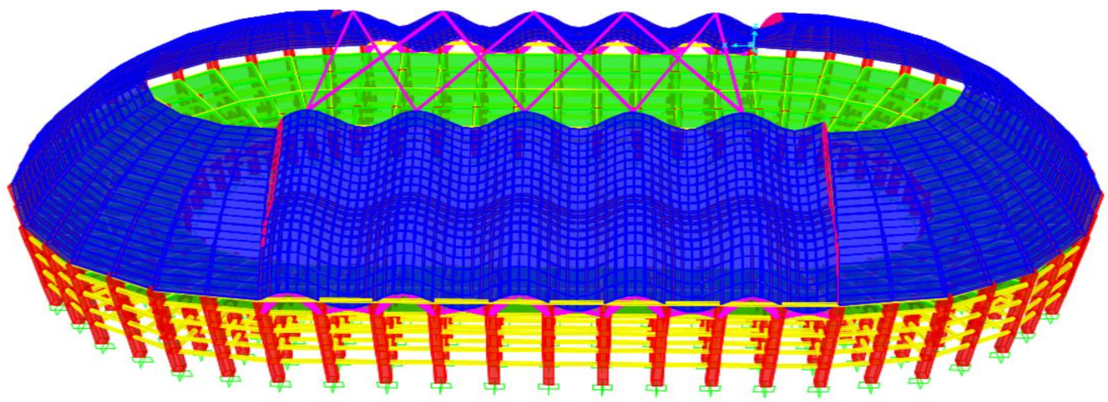


Figure 8 : Bracing Only on top of the stadium with Varying Thickness of Shell in RCC Sap 2000

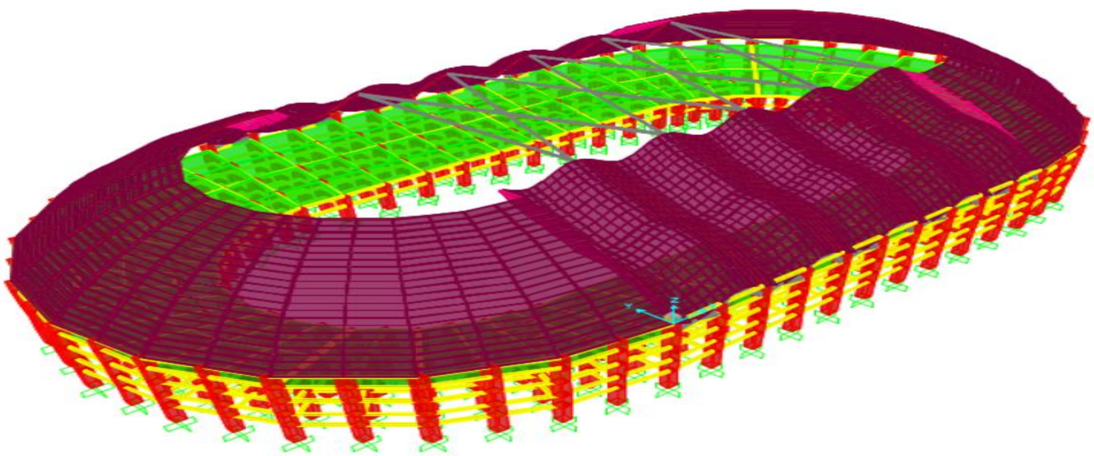


Figure 9: Bracing only on top of the stadium with uniform Thickness of Steel Shell in Sap 2000

RESULTS AND DISCUSSION

For observing structural performance using different methods the model of whole superstructure of stadium is modeled in Sap2000 (clause 2.5.2.2 to Clause 2.5.2.14) and analyse result are obtained and Para sine and Dome Part is coded in to the already build up program FORTRAN (clause 2.5.2.1 and Annex I) and analyse results are obtained then the output results are compared (clause 3.1 to 3.5).

For observing structural parameters the shell structure in sap2000 as well as FORTRAN are observe specific ultimate parameters subjected to gravity load.

For study structural parameters of roof shell structure models with varied and uniform thickness are modeled (Clause 2.5.2.16 to clause 2.5.2.24) then analsyed and the result are compared with structural parameters.

For observing structural performance shell roof structure with stiffeners and without stiffened bracing the deformation of the critical joint in the shell roof structure is obtained (clause 3.1 &

3.2) and bracing at the top of the roof (clause 3.3) is analysed to obtained the deformation of the critical joint is obtained then the results are compared to achieve permissible deflection.

Using FORTRAN complex, sap2000 and with manual verification (IS 456:2000 clause 23.2 span/350 or 20mm whichever is less) deviation in results are seen due to effect of methodologies empirical formulas and discontinuities of curvature under consideration. However, it is noted that not peak deviation is occurred while using various methods.

Stress goes increasing at the base of the dome and para sine part so contour act the stress variation of thickness of the slab is done for getting the structural performance. Also dead and lateral loads are decreased due to the thickness of the slab which ultimately decrease the permissible deflection of the tip of the stadium roof.

At the junction of roof and super structure and intersection of para sine and dome of the stadium stress concentration is maximum, to contour act this thickness of slab is vary.

Comparison Base Reaction of Four Models

TABLE 8 BASE REACTIONS DUE TO GLOBAL FZ (KN)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	586568.10	570414.90	676595.98	660310.72
EQX	0.00	0.00	0.00	0.00
EQY	0.00	0.00	0.00	0.00
LIVE	36563.25	36563.25	36563.25	36563.25

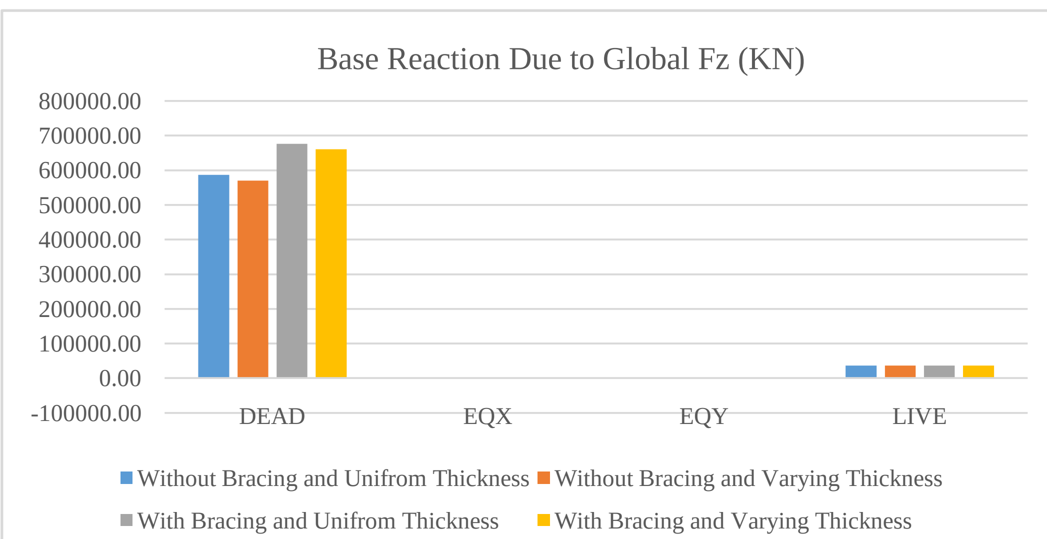


TABLE 9 BASE REACTIONS DUE TO GLOBAL FX (KN)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	0.00	0.00	0.00	0.00
EQX	-841227.33	-819420.51	-962764.96	-940779.84
EQY	0.00	0.00	0.00	0.00
LIVE	0.00	0.00	0.00	0.00

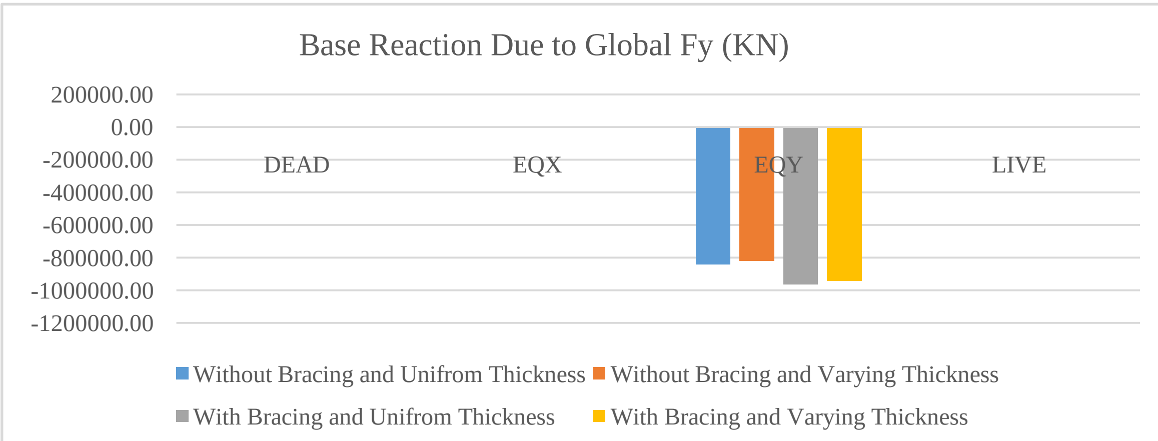


TABLE 10 BASE REACTIONS DUE TO GLOBAL F_Y (KN)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	0.00	0.00	0.00	0.00
EQX	0.00	0.00	0.00	0.00
EQY	-841227.36	-819420.53	-962764.98	-940779.80
LIVE	0.00	0.00	0.00	0.00

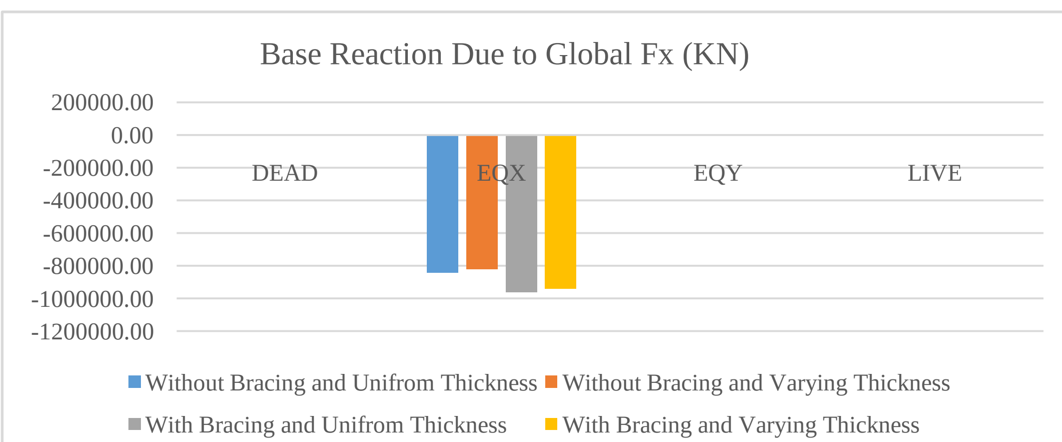


TABLE 11 BASE REACTIONS DUE TO GLOBAL M_Z (KN-M)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	0.00	0.00	0.00	0.00
EQX	42103513.70	41014625.80	48181787.80	47093372.70
EQY	-33739480.00	-32864066.00	-38629929.00	-37737671.00
LIVE	0.00	0.00	0.00	0.00

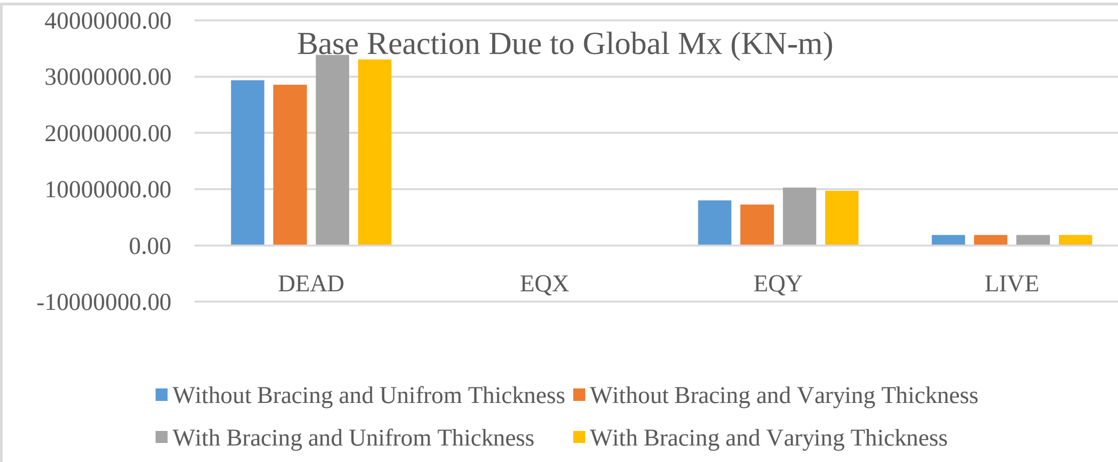


TABLE 12 BASE REACTIONS DUE TO GLOBAL M_X (KN-M)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	29357793.27	28550849.54	33860316.10	33050887.30
EQX	0.00	0.00	0.00	0.00
EQY	7990814.33	7254729.66	10296099.29	9722439.50
LIVE	1829994.38	1829994.38	1829994.38	1829994.38

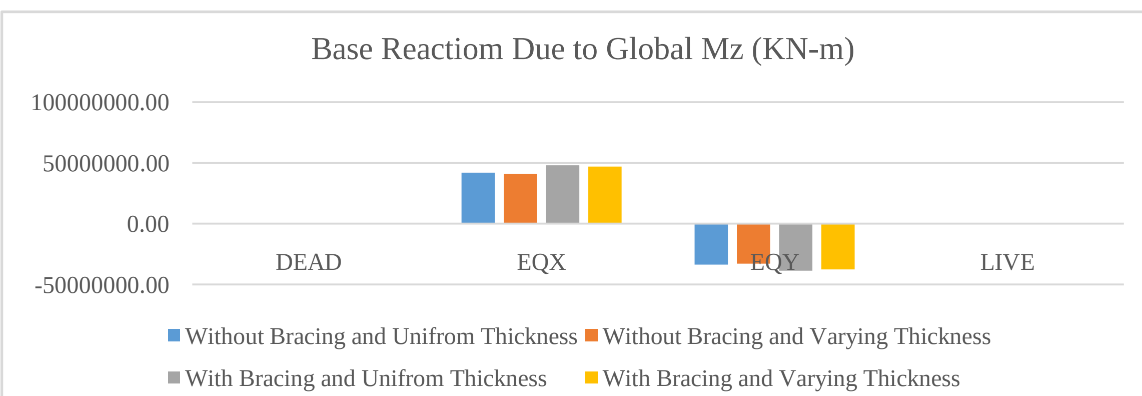
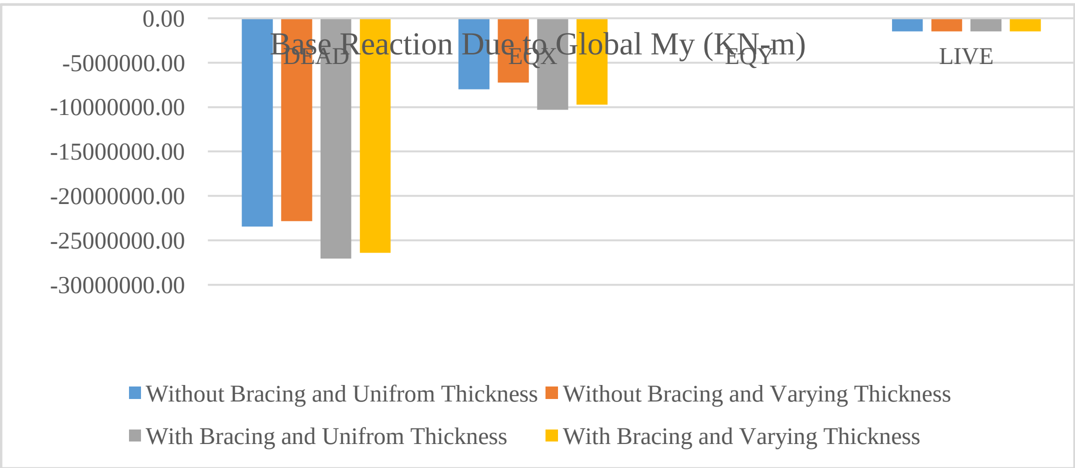


TABLE 13 BASE REACTION DUE TO GLOBAL MY (KN-M)

Output Case	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
DEAD	-23462787.00	-22816548.30	-27064243.00	-26411013.00
EQX	-7990814.00	-7254729.40	-10296099.10	-9722439.80
EQY	0.00	0.00	0.00	0.00
LIVE	-1462529.87	-1462529.87	-1462529.87	-1462529.87



Comparison Displacement of Four Models

TABLE 14 DISPLACEMENT U3 (M) DUE TO DEAD LOAD

Displacement U3 (m) due to Dead load	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4443	-1.499236	-1.63802	-1.734651	-1.585052
Joint 4427	-2.157654	-2.354676	-2.497429	-2.284484
Joint 4416	-2.027666	-2.2132	-2.346938	-2.146438
Joint 4417	-1.89592	-2.069722	-2.194339	-2.006557
Joint 4386	-1.7639	-1.926	-2.0414	-1.866343
Joint 4330	-1.632066	-1.782557	-1.888593	-1.726215
Joint 4387	-2.340849	-2.553237	-2.708964	-2.479149
Joint 4393	-2.250026	-2.454928	-2.604151	-2.382614
Joint 4388	-2.431348	-2.651166	-2.813258	-2.575256
Joint 4394	-2.522515	-2.749865	-2.917964	-2.67181

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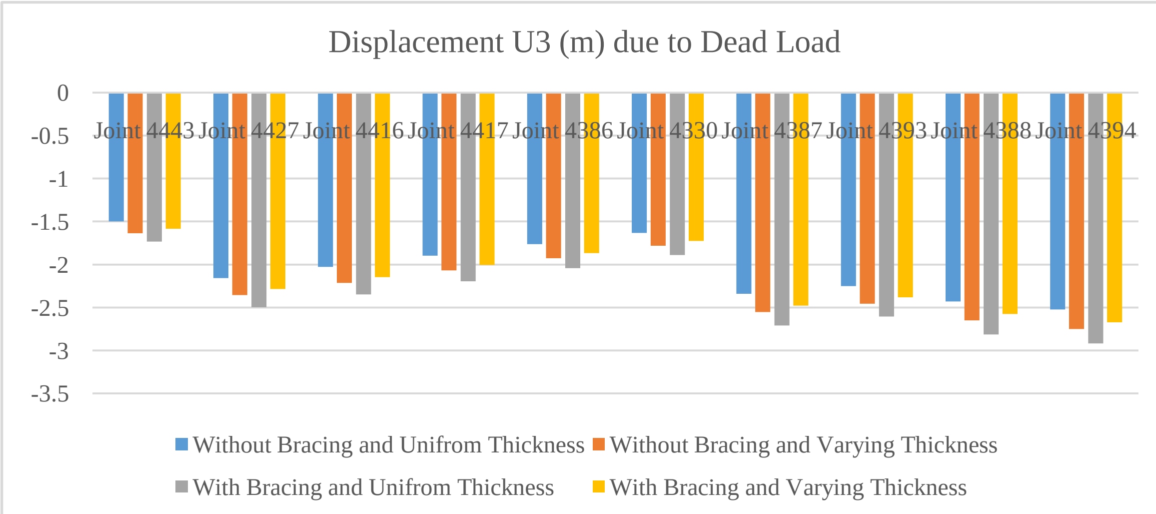


TABLE 15 DISPLACEMENT U1 (M) DUE TO EQX

Displacement U1 (m) due to Eqx	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4330	0.170708	0.162946	0.18502	0.171444
Joint 4394	0.175495	0.168258	0.192257	0.178433
Joint 4393	0.174621	0.167263	0.190914	0.177136
Joint 4388	0.173708	0.166235	0.189524	0.175792
Joint 4387	0.172739	0.165161	0.188081	0.174398
Joint 4386	0.171763	0.164091	0.186584	0.172954
Joint 4417	0.175	0.167617	0.191967	0.178489
Joint 4416	0.175312	0.168021	0.192179	0.178518
Joint 4427	0.174627	0.167136	0.19167	0.178393
Joint 4443	0.174222	0.166603	0.191286	0.178238

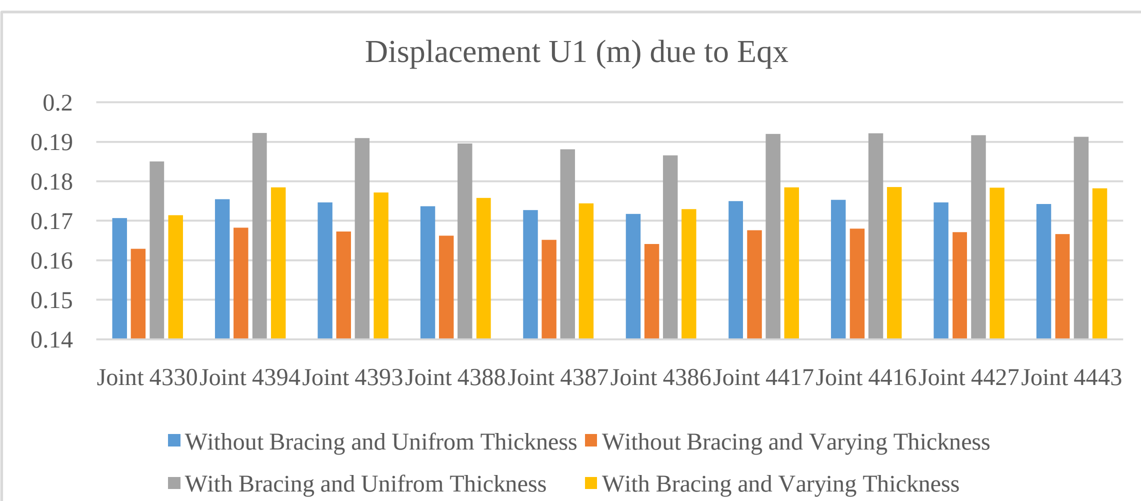


TABLE 16 DISPLACEMENT U2 (M) DUE TO EQY

Displacement U2 (m) due to EQy	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4330	4.12389	4.430562	4.167875	3.686667
Joint 4394	5.580043	5.995938	5.619715	4.968169
Joint 4393	5.292151	5.68632	5.332872	4.714996
Joint 4388	5.000719	5.372887	5.042408	4.45868
Joint 4387	4.708982	5.059254	4.751516	4.201939
Joint 4386	4.417571	4.746116	4.460806	3.945303
Joint 4417	6.139296	6.595681	6.17561	5.459839
Joint 4416	5.861961	6.298568	5.900076	5.216001
Joint 4427	6.415535	6.891527	6.449682	5.702491
Joint 4443	6.69365	7.18943	6.724708	5.946204

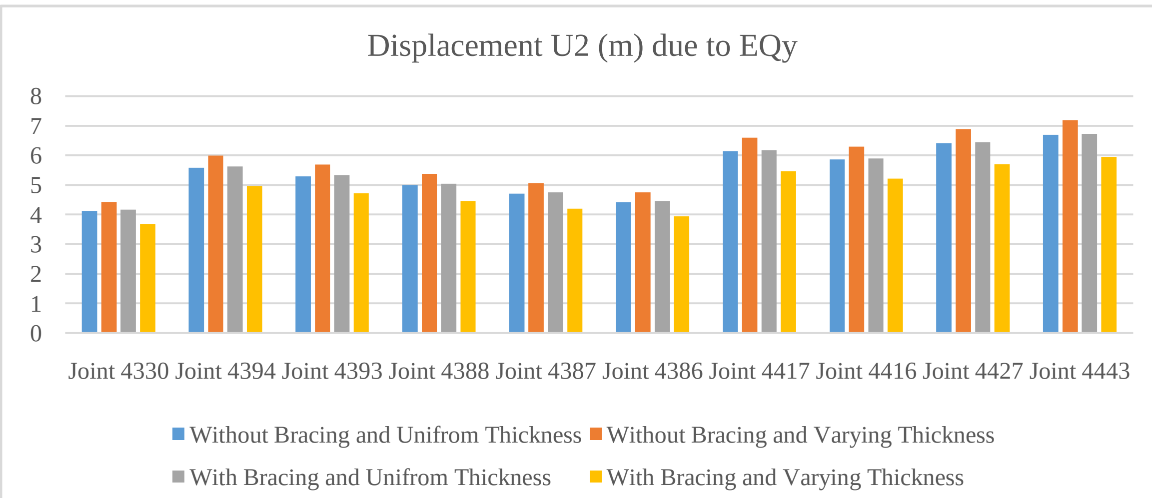
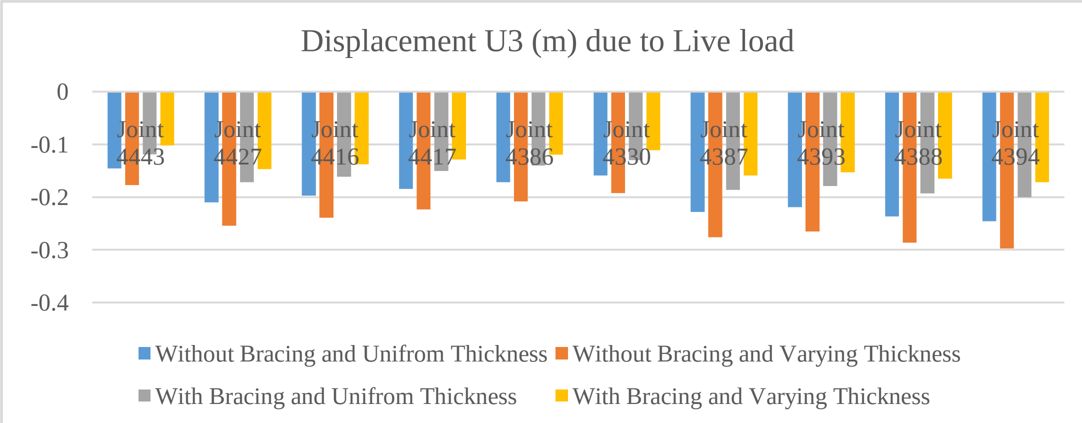


TABLE 17 DISPLACEMENT U3 (M) DUE TO LIVE LOAD

Displacement U3 (m) due to Live load	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4443	-0.145964	-0.17696	-0.119079	-0.101734
Joint 4427	-0.210126	-0.254495	-0.171509	-0.146665
Joint 4416	-0.197457	-0.239185	-0.161163	-0.137795
Joint 4417	-0.184618	-0.223662	-0.150674	-0.12881
Joint 4386	-0.171753	-0.208113	-0.140162	-0.119803
Joint 4330	-0.158906	-0.192595	-0.129659	-0.110801
Joint 4387	-0.227989	-0.27599	-0.18606	-0.159179
Joint 4393	-0.219132	-0.265346	-0.178849	-0.152972
Joint 4388	-0.236814	-0.286593	-0.193236	-0.165358
Joint 4394	-0.245705	-0.297279	-0.20044	-0.171567



Comparison of Displacement of Four Models with Bracing at the Top

TABLE 18: DISPLACEMENT U3 (M) DUE TO COMBINATION OF DEAD AND LIVE LOAD

Displacement U3 (m) due to Combination of Dead and Live load	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 250	-0.251182	-0.19897	-0.309225	-0.255127
Joint 263	-0.261033	-0.206948	-0.321416	-0.265283
Joint 3924	-0.25228	-0.200373	-0.312779	-0.261172
Joint 3925	-0.243024	-0.192781	-0.301079	-0.251363
Joint 3934	-0.243626	-0.192909	-0.303073	-0.255585
Joint 7508	-0.251179	-0.20016	-0.310368	-0.255035
Joint 7509	-0.26103	-0.208188	-0.322608	-0.26519
Joint 7746	-0.252278	-0.201834	-0.314169	-0.261101
Joint 7747	-0.243023	-0.194179	-0.302416	-0.251291
Joint 7756	-0.243626	-0.19459	-0.304661	-0.255534

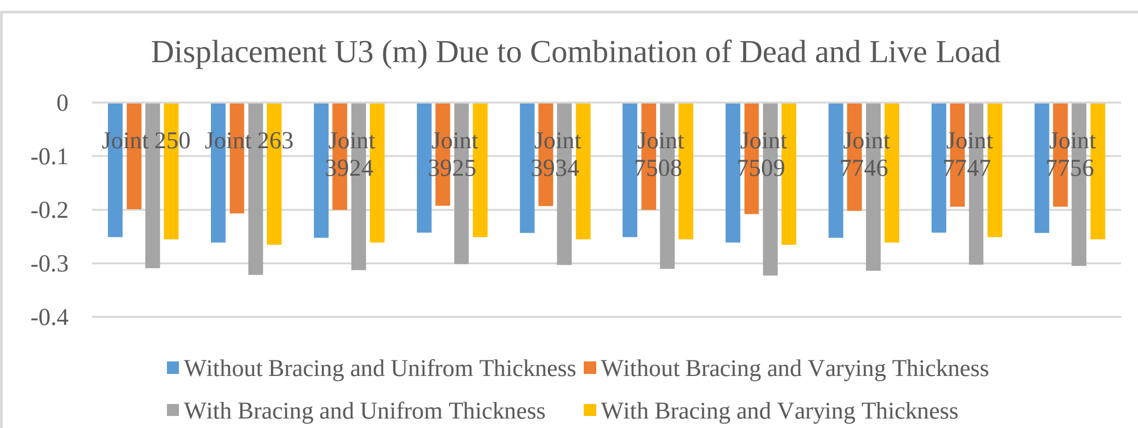


TABLE 19: DISPLACEMENT U3 (M) DUE TO DEAD LOAD

Displacement U3 (m) due to Dead Load	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 250	-0.150085	-0.115972	-0.18817	-0.156295
Joint 263	-0.155968	-0.120616	-0.195588	-0.162513
Joint 3924	-0.150892	-0.116924	-0.190514	-0.160136
Joint 3925	-0.145359	-0.112512	-0.183388	-0.154131
Joint 3934	-0.145868	-0.112723	-0.184783	-0.15686
Joint 7508	-0.150084	-0.116689	-0.188831	-0.156221
Joint 7509	-0.155966	-0.121363	-0.196277	-0.162437
Joint 7746	-0.150891	-0.117804	-0.19132	-0.160075
Joint 7747	-0.145358	-0.113353	-0.184164	-0.15407
Joint 7756	-0.145868	-0.113734	-0.185707	-0.156811

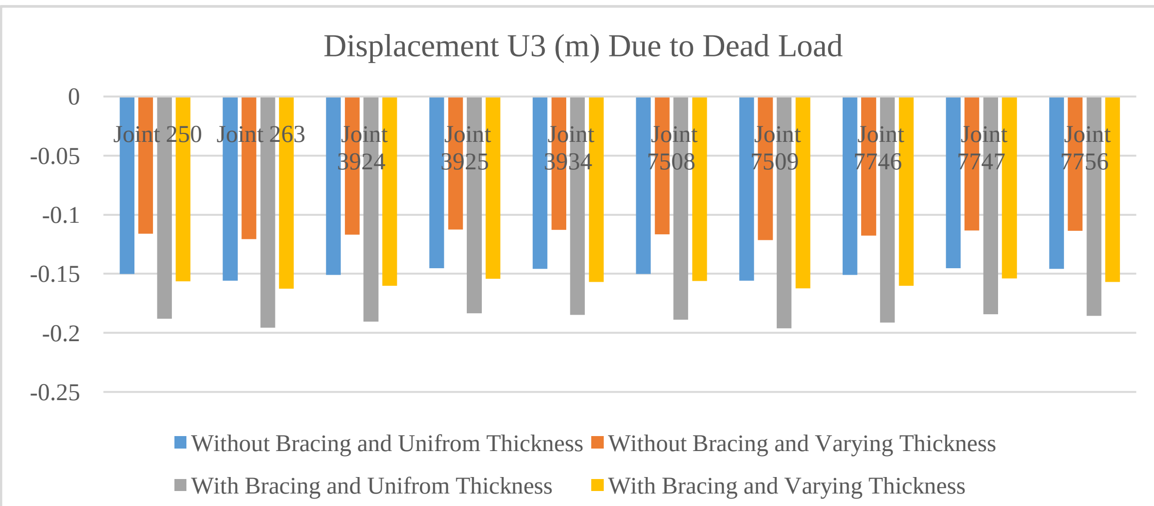


TABLE 20: DISPLACEMENT U3 (M) DUE TO LIVE LOAD

Displacement U3 (m) due to Live Load	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 250	-0.01737	-0.016675	-0.01798	-0.01798
Joint 263	-0.018054	-0.017349	-0.018689	-0.018689
Joint 3924	-0.017294	-0.016657	-0.018006	-0.018006
Joint 3925	-0.016657	-0.016009	-0.017331	-0.017331
Joint 3934	-0.016549	-0.015883	-0.017266	-0.017266
Joint 7508	-0.017369	-0.016751	-0.018081	-0.018081
Joint 7509	-0.018054	-0.017429	-0.018795	-0.018795
Joint 7746	-0.017294	-0.016752	-0.018126	-0.018126
Joint 7747	-0.016657	-0.016099	-0.017446	-0.017446
Joint 7756	-0.016549	-0.015993	-0.017401	-0.017401

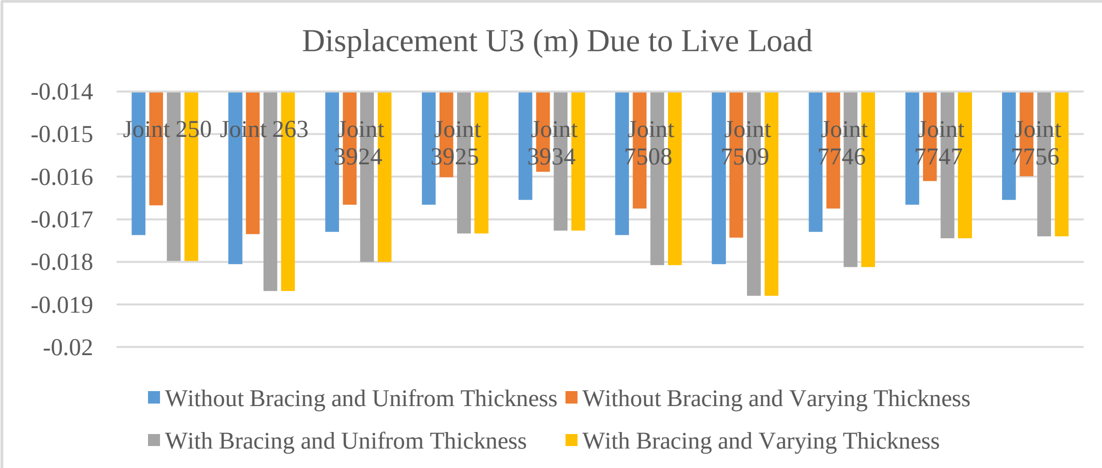


TABLE 21: DISPLACEMENT U1 (M) DUE TO E_{QX}

Displacement U1 (m) due to Eqx	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4909	0.270648	0.26182	0.027503	0.300082
Joint 4914	0.267513	0.258045	0.027131	0.296018
Joint 4915	0.273278	0.263834	0.027806	0.302333
Joint 4916	0.270697	0.261938	0.027512	0.300097
Joint 4917	0.265082	0.256262	0.026856	0.293959
Joint 8729	0.265039	0.256174	0.026851	0.29335
Joint 8730	0.270651	0.261852	0.027503	0.29942
Joint 8735	0.267516	0.258078	0.027131	0.295399
Joint 8736	0.27328	0.263865	0.027806	0.301651
Joint 8737	0.270699	0.261969	0.027512	0.299439

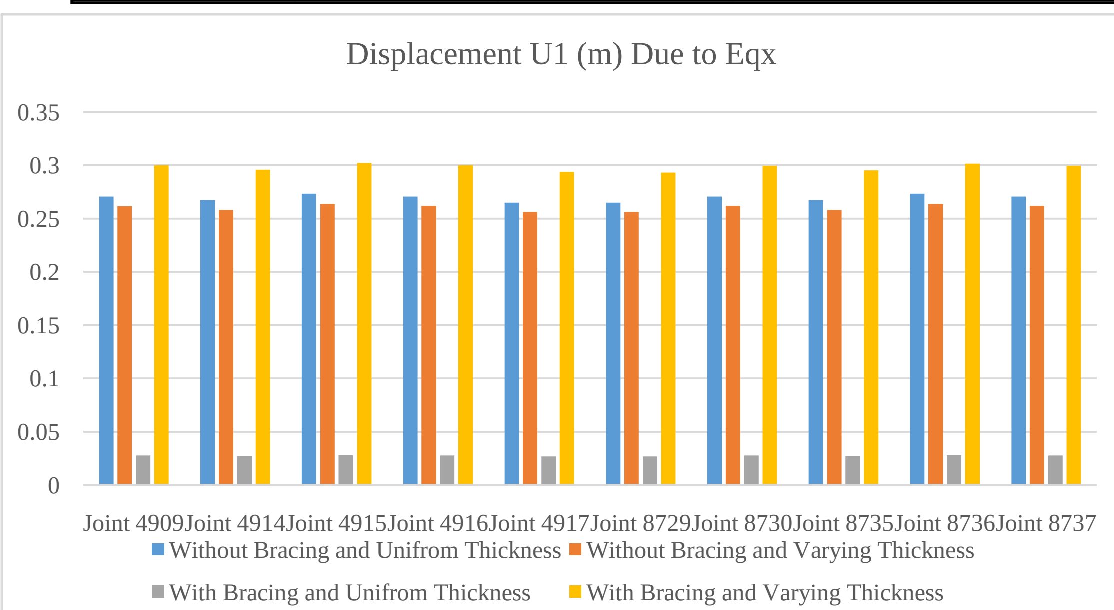


TABLE 22: DISPLACEMENT U2 (M) DUE TO EQY

Displacement U2 (m) due to Eqy	Without Bracing and Unifrom Thickness	Without Bracing and Varying Thickness	With Bracing and Unifrom Thickness	With Bracing and Varying Thickness
Joint 4151	18.281103	4.762014	0.553104	18.235122
Joint 4153	18.781083	4.875066	0.568899	18.727186
Joint 4159	18.901529	4.883385	0.573106	18.844203
Joint 4160	18.655757	4.859345	0.566272	18.630993
Joint 4405	18.656762	4.873174	0.562123	18.703877
Joint 4411	18.911894	4.900974	0.569722	18.920379
Joint 4412	18.784167	4.886688	0.565731	18.786696
Joint 4443	18.272707	4.766857	0.550123	18.273278
Joint 7973	18.281202	4.763121	0.553162	18.235263
Joint 7975	18.781179	4.876136	0.568955	18.727269

Comparison of Displacement of FORTAN and Model with Bracing and Uniform Thickness

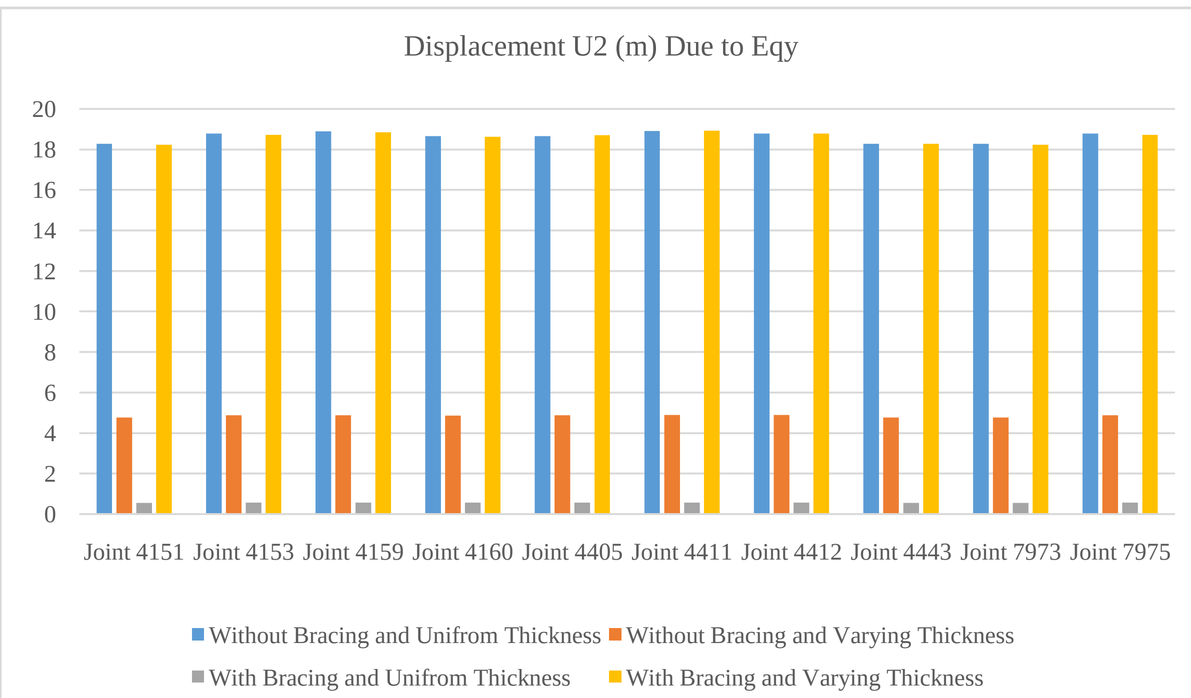


Table 23: Comparison of Displacement Result along Sine Part Due to Dead Load of FORTAN and Sap Model with Bracing and Uniform Thickness

Joints	FORTAN	With Bracing and Unifrom Thickness
Joint 7487	-0.07381	-0.10036
Joint 7495	-0.22350	-0.11631
Joint 7499	-0.37530	-0.11664
Joint 7501	-0.49380	-0.12108
Joint 7505	-0.56630	-0.12678
Joint 7509	-0.59050	-0.19132

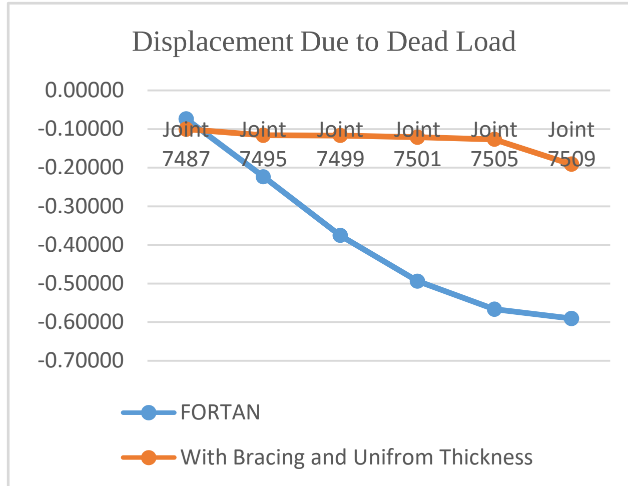


Table 24: Comparison of Displacement Result along Para Part Due to Dead Load of FORTAN and Sap Model with Bracing and Uniform Thickness

Joints	FORTAN	With Bracing and Unifrom Thickness
Joint 7487	0.00000	-0.01650
Joint 7495	0.01719	-0.05066
Joint 7499	0.01922	-0.09569
Joint 7501	-0.14340	-0.12640
Joint 7505	-0.39840	-0.16699
Joint 7509	-0.59050	-0.19628

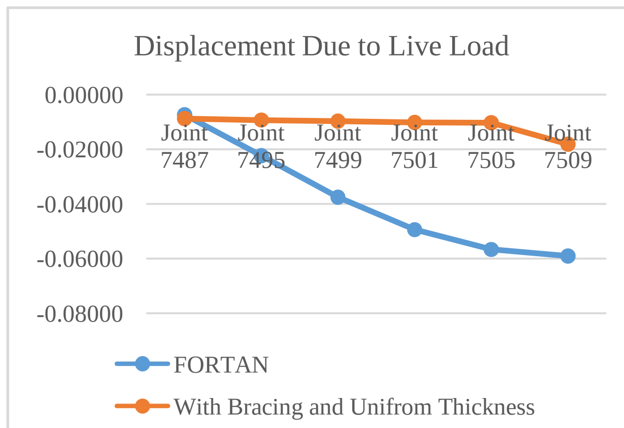


Table 25: Comparison of Displacement Result along Sine Part Due to Live Load of FORTAN and Sap Model with Bracing and Uniform Thickness

Joints	FORTAN	With Bracing and Unifrom Thickness
Joint 7487	0.00000	-0.00033
Joint 7495	0.00172	-0.00480
Joint 7499	0.00192	-0.00916
Joint 7501	-0.01434	-0.01211
Joint 7505	-0.03984	-0.01600
Joint 7509	-0.05905	-0.01880

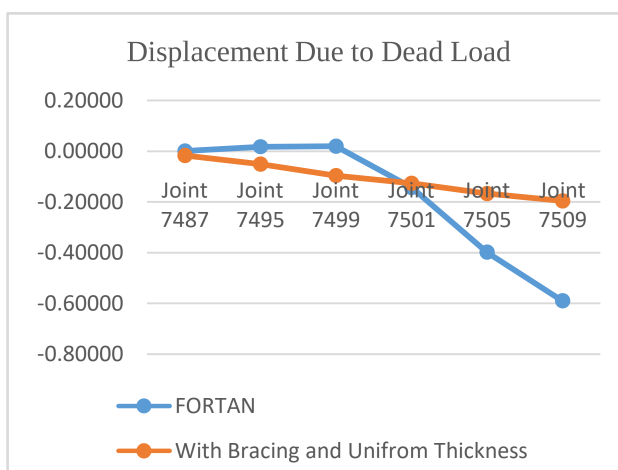
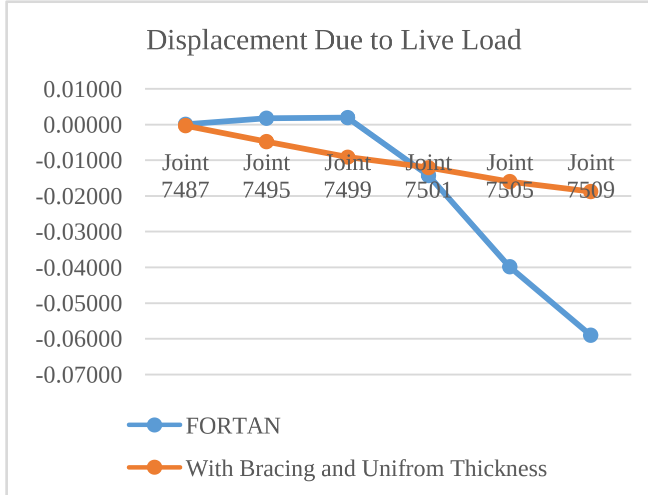


Table 26: Comparison of Displacement Result along Para Part Due to Live Load of FORTAN and Sap Model with Bracing and Uniform Thickness

Joints	FORTAN	With Bracing and Unifrom Thickness
Joint 7487	-0.00738	-0.00871
Joint 7495	-0.02235	-0.00925
Joint 7499	-0.03753	-0.00964
Joint 7501	-0.04938	-0.01013
Joint 7505	-0.05663	-0.01022
Joint 7509	-0.05905	-0.01813



Comparison of Displacement of FORTAN and Model without Bracing and Uniform Thickness of Steel Plate

Table 27: Comparison of Displacement Result Due to Dead Load of FORTAN and Sap Model without Bracing and Uniform Thickness of Steel Plate

Joints	FORTAN	With out Bracing and Unifrom Thickness of Stell Plate
Joints 8044	-0.00949	-0.10451
Joints 8092	-0.02873	-0.05471
Joints 8116	-0.04825	-0.02982
Joints 8206	-0.06349	-0.20024
Joints 8217	-0.07281	-0.15356
Joints 8264	-0.07592	-0.23290

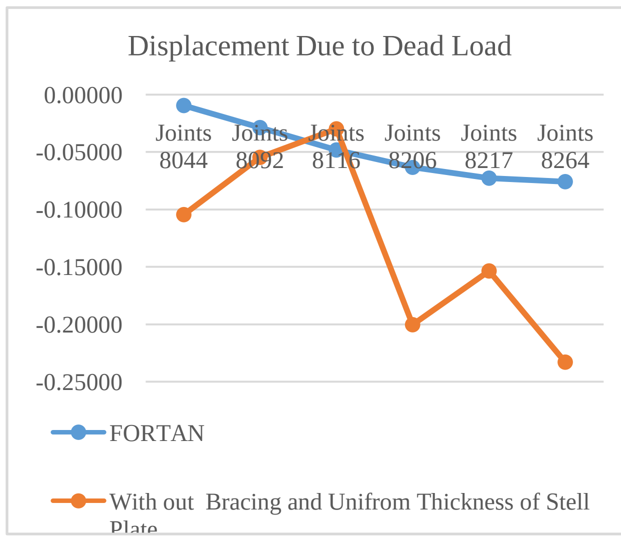
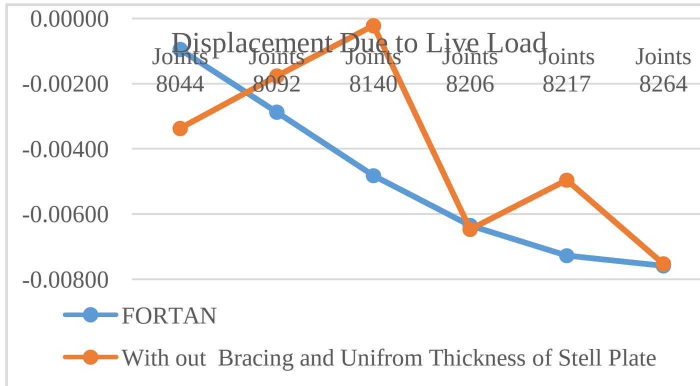


Table 28: Comparison of Displacement Result Due to Live Load of FORTAN and Sap Model without Bracing and Uniform Thickness of Steel Plate

Joints	FORTAN	With out Bracing and Unifrom Thickness of Stell Plate
Joints 8044	-0.00095	-0.00337
Joints 8092	-0.00287	-0.00177
Joints 8140	-0.00483	-0.00022
Joints 8206	-0.00635	-0.00647
Joints 8217	-0.00728	-0.00496
Joints 8264	-0.00759	-0.00753



DISCUSSION

Form the result obtained above, the following observation was made:

Discontinuous function is not calculated by sap2000 and FORTAN complex only perform by elastic theory approach. Due to this the variation of results occurs greater as we aspect.

Discussion no 1.

Stadium Roof Structure without Bracing Uniform Thickness of shell, without bracing Varying Thickness of Shell, with bracing uniform thickness of shell and with bracing varying thickness of shell Model

Through comparison of displacement obtained by different models of roof structure, the displacement of the critical point of the roof is over the permissible displacement.

Discussion no 2.

Stadium Roof Structure with bracing at the top of roof in four model without Bracing with Uniform Thickness of shell, without bracing and Varying Thickness of Shell, with bracing and uniform thickness of shell and with bracing and varying thickness of shell Model

Through comparison of displacement obtained by different models of roof structure, the displacement of the critical point of the roof is in the limit of permissible displacement.

Discussion no 3.

Stadium Roof Structure model bracing with Uniform Thickness of shell and FORTRAN

Through comparison of displacement obtained by models of roof structure and FORTRAN, the displacement of the critical point of the roof are observed due to adopting continuity by manual and FORTRAN complex are observed not exceeding permissible limit of deflection.

Discussion no 4.

Stadium Roof Structure model without bracing and Thickness steel plate of shell and FORTRAN

Through comparison of displacement obtained by models of roof structure without bracing and thickness steel plate and FORTRAN, the displacement of the critical point of the roof different deflections are observed for bracing system and material assigned converting RCC shell roof in to steel.

Final Real Stadium with dome as well as para sine parts

Using sap2000 and getting the results in FORTAN (specific parts) following outputs are achieved

1) In intersecting line of dome and para-sine stress concentration seen but rectified using connecting members.
2) The permissible limit of deflection is achieved by connecting peak of para sine.
3) Different deflections are observed for bracing system and material assigned converting RCC shell roof in to steel.

CONCLUSION

- The varying thickness of RCC shell has important rule to minimize tip deflection up to permissible limit, stress concentration and stiffness through bracing system of shell structure used in roof of stadium.
- The para sine form Mongue's surface curved shell roofs with super structure intersected to the adjacent dome structure are found stable in both gravity and lateral loads during analysis.
- The considerable alternation in different adapted methodology to achieve structural parameters of roof shell structure having uniform and varying thickness are observed due to adopting continuity by manual and FORTRAN complex are observed not exceeding permissible limit of deflection.
- The permissible deflection undergo by different kinds of load in shell roof structure is achieved with lateral, diagonal stiffeners at the roof top and bracing within shell structure.
- The intersection portion of dome and para sine should be braced by using stiffener to overcome stress concentration in intersection line of those connect parts of dome and para sine.

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