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R.C.C Shell Structure Design of Selected Head Cap Shape

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Abstract:** A shell structure is a thin structure composed of curved sheets of material, so that Shell structures are inspired from natural element named "SHELL". A thin curved member or slab usually of reinforced concrete that function as tension member and shell. The waviness plays an important role in the structural behavior realizing a spatial form. Some of natural elements like eggshell, seashell, fruit shells (walnut) etc are showing shell structure properties. The present reinforced concrete shells as a very efficient structure, spanning wide, architectonically beautiful, relevant and valuable structural solution. Shell structures are very attractive lightweight structures, which are especially suited to Architectural building, industrial application, commercial projects etc.. The actual design of shells, involves theories of shells and the use of appropriate codes of practice. Types of curved shell like Parabolic, Hyperbolic or Cylindrical members are often said to act as tension rigidity hence called tensile members. For achieving the optimized load capability and flexural strength of such an element in form of shell covering structure is checked in for M30 grade concrete. Tensile shell members are structural edifice that caries only tension and without buckling or bending. Tensile structures are the most common type of thin-shell structures used worldwide from past decades. The profile and aspect of structure used are unlike for loading conditions, geographical locations and Architecture design differs as such as horizontal, sloping or curved member (dome and shell member). In this research work the tensile shell (plate) structure is designed in the form of beam and as grid shell slab element (plate). After then load has been applied for analysis via software tool i.e. STAAD Pro. The types of load assigned dead and live loads. The Design code specifications for curved shell member in IS: 2210–1994, IS 2204-1962 "Code of practice for construction of reinforced concrete shell roof" [CED 13: Building Construction Practices including Painting, Varnishing and Allied Finishing] and the load case criteria is to be as per IS: 875(2)–2000. RCC design specifications as per IS: 456–2000.

***Keywords:** Shell Structures, Reinforced concrete shells, Lightweight structures, STAAD Pro*

I. INTRODUCTION

A concrete shell is also commonly called thin shell concrete structure. It is a structure composed of a thin shell of concrete, usually with no interior columns or exterior support. The most commonly shapes of shell are flat plates, curved and domes. It may also take the form of parabolic, hyperbolic, ellipsoids or cylindrical sections, and its combinations. Concrete shell structures are created for a large span with a minimal amount of material. In the maintaining this economy of material, these forms have a Light, Aesthetically, Architectural Appeal. Shells are spatially curved shaped structures, which support external applied loads. Considerably shell structure is adroitly able to bear direct bending stresses due to its stressed skin structure As per IS 2210: 1988. In General - Shells may be broadly classified as 'singly-curved shell' and 'doubly-curved shell'. This is based on Gauss curvature theory. According theory of the gauss curvature value of singly curved shells is zero because one of their principal curvatures is zero. Doubly curved shells are non developable shells. It is classified into synclastic and anticlastic according as their Gauss curvature value is +ve or -ve. Lanky shell concrete structures are structurally efficient systems for covering world architecture. However, their construction has seen a sharp decline since their golden period between the 1920s and early 1960s, with the possible exception of air-inflated domes. Commonly cited reasons for their disappearance are the cost of formwork and the rising cost of associated labor with the declining interest from architects. Thin shell concrete structures are pure compression structures formed from combination of inverse curved shapes. Inverse curved are those taken by any material when allowed to hang freely under their own weight. The free hanging form is in pure tension, as string can bear no compression. Compression is ideal for concrete because concrete has very high compressive strength and very low tensile strength that helps shapes maximize the influence of concrete, allowing it to form thin and lightweight span structures.

The effort in the design of shell as thin as per architecture and structural view, so that the dead weight is reduced and the structure functions free from the large bending stresses. By this means, a minimum of materials is used to be the maximum structural advantage with well favored. Exemplification of natural shell structures include coconut shells, tortoise shells, seashells and nutshells, man-made shell structures include tunnels, roofs, helmets, drink cans and boats etc.

II. LITERATURE REVIEW

1) *Niranjan. B. Satyannavar et. al. (2022)* **-** In this paper, pre-stressed precast critical shell roof structures are proposed as an alternative in difference to conventional roof structures. Arrange of shell roof best utilizing backed concrete is amazingly challenging. To contradict the tall strain in base harmony, the considerable bolster ought to be pre-stressed. Here, the showing of different setups of prestressed precast substantial shell roof structures is wrapped up utilizing Staad pro v8i programming by changing its scientific boundaries, for example, shapes, incline, length and scattering of the back and examination and streamlining is done to discover the most excellent and best prestressed precast considerable Shell roof structures plans fit to diverse circumstances attainable way of life implies reconsidering our approaches to daily life, how we buy and how we sort out our day to day presence. It is likewise about adjusting how we blend, exchange, share, taught and build identities. It suggests changing our social orders and living in understanding with our common territory. As inhabitants, at domestic and at work, a huge number of our choices - on energy use, transport, nourishment, squander, correspondence and backbone - contribute towards building prudent ways of life In India, customary hones that are attainable and climate well-disposed keep on being a bit of individuals' lives. India contains a past filled with moo carbon impression and way of life. These ought to be energized, instead of supplanted by more current yet unreasonable hones and progressions. This is often moreover pertinent to other non-industrial countries where there's a developing interest in elective models of headway, and on re-establishing green cognizance drawing on ordinary social orders.
2) *Gulzar H. Barbhuiya et. al. (2021)* **-** This ponder is concentrate on the examination of the stresses by utilizing the Fourier arrangement and Schorer's hypothesis. Encourage, the shell is outlined for the steel support as per the Concrete Fortifying Steel Established (CRSI) Plan Handbook after calculating the ultimate stretch resultants and the specifying is additionally expressed. The ought to come up with temperate and effective basic plan conduct by the engineers and analysts to center more on shell structures. It is more strong, conservative because it requires a least sum of fabric gives bigger insides space and engineering tasteful. A shell absurdly carries on as a layer, though, at the edges and twisting stresses get concentrate. Indeed in spite of the fact that a few hypotheses have been put forward, Schorer's hypothesis is famous within the examination of the long span lean round and hollow shells.
3) *Thi My Dung Do et. al. (2021)* **-** In this multilayer bended shell roof, it is fundamental to explore the impact of thickness of layers, the impact of the area of the steel strands concrete layer and the impact of steel filaments substance contained in concrete on the state of push and strain and construct connections, load-vertical uprooting and stretch within the x and y directions of the shell within the examined cases. So, this paper presents an ANSYS numerical recreation think about related to the state of push and strain in double-layer doubly bended concrete shell roof with the introductory parameters being changed such as the thickness of the layers, the location of the steel filaments concrete layer within the structure (the steel strands concrete layer that's put over and underneath the typical concrete layer), and the steel filaments substance contained in concrete shell with the measure of 3000 × 3000 mm, which is mimicked by ANSYS after being tentatively conducted on this bended shell roof; the comes about of test and recreation ponder are confirmed by each other. Investigate comes about appear that the thickness of the steel strands concrete layer is put underneath the typical concrete layer, the rate of steel strands contained within the concrete is 2%, and the bearing capacity of the bended shell is ideal.
4) *Tanvi Lad et. al. (2021)* **-** This paper centers on comparative think about of diverse sorts of shell structure. Shell structures are not fair simple aesthetics but moreover a cutting edge engineering adaptation of inventive development procedures. Through efficient comparison of case thinks about, this audit paper moreover emphasizes on the applications and development strategies that wins in this sort of long span basic framework and highlights the scope for shell structures.
5) *Laith N. Hussain Et. Al. (2020)* **-** This think about tries to make strides the basic execution of the arch shell itself additionally to choose the finest strategy to examine the shell of arches with large diameters. In this way, the show consider includes four strategies to improve hell basic conduct. The primary strategy is to strengthen shell with diverse rates and areas of steel bars (in beat and foot fiber or both). The moment strategy is to upgrade shell basic execution by including ribs pillar. The third strategy is done by resting shell on ring pillar, while, the final strategy is done by complaining ribs and ring pillar together. The strategy incorporates emission of circular arches that have huge distances across of 23. 5 m with thickness measurement of 0.14 m. To

dissect the four strategies, four distinctive limited component models have been done utilizing ANSYS V.16.2. The think about found out that fortifying shells by steel bars with a shifted sort cent ages and distinctive areas have the little impact to optimize shell execution as demonstrated by shear push graph and split obvious. On the other hand, rib bars contributed to deduct and interpret meridian and loop stresses absent from rib beams only. There's a slight commitment to extend the greatest stack Capacity of shells in both of the primary and the moment cases; something else there's a sensational alter in extreme stack capacity for arches which are resting on ring bar. Resting shell on the ring bar gives diverse practices for arch. The most extreme esteem of diversion has been recorded on the best of this sort of arch which was break even with to 10.2 mm and the expansion of two steel bar layers increment the greatest avoidance to 14.6 mm. For all cases, there's no alter in band stretch esteem till a breadth of 8000 mm. When the distance across is more than 8000 mm, band stretch values are expanded for all cases but the shell which rested on shell (2RS-N, 2RS-B-N). Hence, there's no noteworthy alter in circle stretch esteem until a breadth of 12000 mm.

A. Objective Of Study

The objective of the study is to make an illustration of the shell structure. This is a cowboy hat like structure. This is a kind of shopping mall. This structure has a centre dome which rests on a number of columns. The following steps have been taken from making this structure to designing:

1) Selection of shape of shell structure.
2) Modelling with the help of Revit Architecture Software.
3) After at that point stack has been doled out for investigation through computer program device i.e. STAAD Pro. The types of load assigned are dead and live loads. The Design codes specifications are provided for curved shell member in IS: 2210– 1994, IS 2204-1962 “Code of practice for construction of reinforced concrete shell roof” [CED 13: Building Construction Practices including Painting, Varnishing and Allied Finishing]. Load case criteria is to be as per IS: 875 (2)–2000. Reinforced cement concrete design specifications as per IS: 456–2000.
4) Animate this structure with Lumion software with all shopping mall facility.

III. MODELLING OF SHELL STRUCTURE

In this chapter, different modelling parameters related to shell structure are calculated. We also discuss about material property, selection of dimensions, software used and model Consider for study. Modelling and analysis are done in Staad Pro software. For 3D modelling Revit and for animation Lumion Software are used.

TABLE 1
MODELLING DETAILS

S. No.	Description	Value
1	Radius Of Shell	50m
2	Gamma Angle	0° To 360°
3	Radius Of Curvature	6m
4	Span Of Shell (In Z-Direction)	17.5m.
5	Width Of Shell Or Length Of Chord	12.94m.
6	Thickness Of Shell	120mm (0.12m.)
7	Height Of Shell From Plinth To Dom	10m.
8	Slope Of Shell From Outer Ring To Dom's Bottom	4m.
9	Base Diameter Of Spherical Dom	15m.
10	Height Of Spherical Dom From Shell	6m.
11	Grade Of Concrete	M25 And M30
12	Grade Of Steel	FE415
13	Dead Load (Factor)	-1
14	Live Load	0.4 Kn/M (As Per Is-875 Part-Ii-1987 Table 2)
15	Plate Pressure	-0.0025 N/Mm2
16	Soil Type I	Rock, Hard Soil

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A. Material Property

For material properties we follow IS 2210 (1988): Criteria for design of RC shell structures and folded plates.

1) *Concrete:* Controlled concrete shall be used for all shell, and folded plate structures. The concrete is of minimum grade M20. The quality of materials used in concrete and the methods of proportioning and mixing the concrete shall be finish in accordance with the relevant provisions of IS: 456-2000.
2) *Steel:* The steel for the reinforcement shall be: Diameters of Reinforcement Bars The following diameters of bars may be provided in the structure of the shell. Larger diameters may be provided in the thickened portions, transverse reinforcement and beams: Minimum diameter: 8 mm, and Maximum diameter: 1/4 of shell thickness or 16 mm whichever is smaller.

B. Selection of Dimensions

1) *Spacing of Reinforcement:* The maximum spacing of reinforcement in any direction in the body of the shell shall be limited to five times the thickness of the shell and the area of unreinforced panel shall in no case exceed 15 times the square of thickness.
2) *Slope:* Generally, if the slope of shell exceeds 45°, it will be too steep for easy concreting.
3) *Thickness of Shells:* Thickness of Shells - Thickness of shells shall not normally be less than 50 mm if singly curved and 40 mm if doubly-curved. This requirement does not, however, apply to small precast concrete shell units in which the thickness may be less than that specified above but it shall in no case be less than 25 mm (see IS : 6332-19842). We adopted 120mm.

C. Software Used

1) *AutoCAD:* The plan of the shell structure has been made with the help of AutoCAD. A part of the shell structure is created by generating multiple nodes. First a circle of 50m diameter was drawn and the perimeter of this circle was divided into 12 equal parts. Part of it shows a ring on the outside of the shell structure.

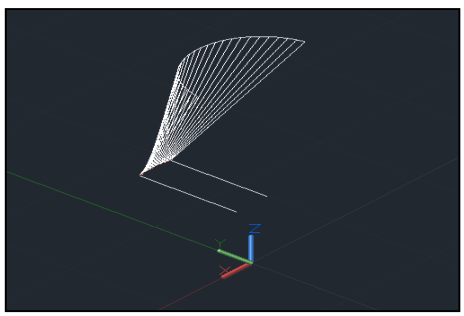

Fig. 1 AutoCAD One Ring Model

2) *Revit:* With the help of its software, a shell structure of 50 diameter and 16m height has been made with outer 12 rings and centre dome of 15m dia. Its plinth height is taken from main road with ramp. Each element is assigned a material that is made realistic in Lumion.

Fig.2 Revit Model

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3) *Staad Pro:* A part of the shell structure obtained from AutoCAD was imported into staad and its multiple nodes were shown. Quad lateral plate was generated with the help of every four nodes. After making all the plates, it was made into 12 parts with the help of circular repeat. After connecting the entire shell structure with plates, the central dome was made from spherical surfaces in the run structure wizard. After the construction of the complete shell structure, it was analysed and designed with the help of materials and loads. Number of Joints - 6148 ; Number of Plates - 5892; Number of Supports - 12.

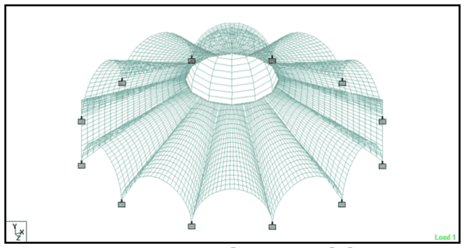

Fig. 3 Staad pro Model

4) *Lumion:* Lumion software is a really effective find, made for a wonderful combination of architecture and animation. The model created on Revit was imported into Lumion and given a realistic view and material.

Fig. 4 3D Model

D. Model Consider for study

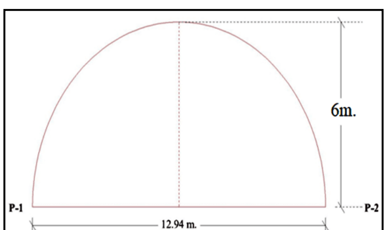

Fig. 5 One Ring Dimensions

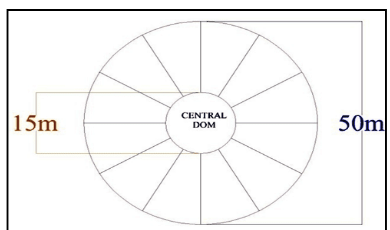

Fig.6 Plan of shell structure

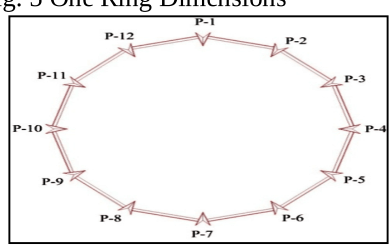

Fig.7 Support points shell structure

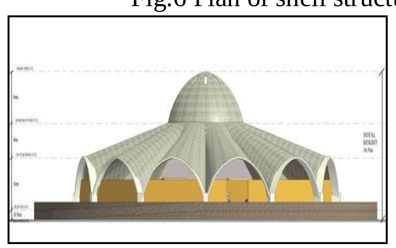

Fig.8 Front view of shell structure

Fig.9 3D Rendering View

Fig.10 Interior View

IV. SHELL ANALYSIS

In previous chapter we discussed about modelling of shell structure. The description of dimensions, load values, angle, material property, selection of dimensions, software used and model Consider for study. This chapter includes all the analysis carried out by the modelling. The Analysis so obtained and compared in the form of figure to present it in easier way along with discussions.

A. *Maximum Absolute Plate Pressure*

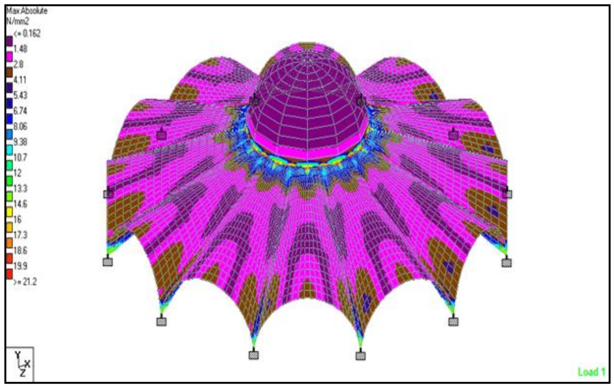

Fig.11 Maximum Absolute Plate Pressure

B. *Maximum Top Principal Major Stress*

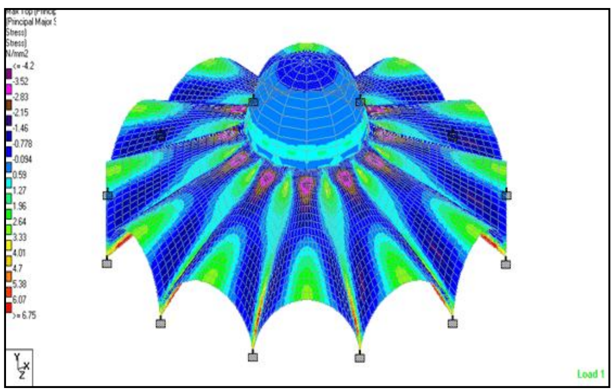

Fig. 12 Maximum Top Principal Major Stress

C. *Minimum Top Principal Minor Stress*

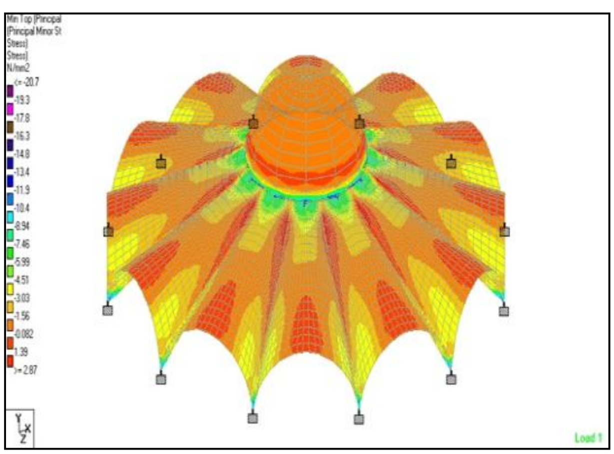

Fig.13 Minimum Top Principal Minor Stress

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D. Support reactions

TABLE 2
SUPPORT REACTIONS

All | Summary | Envelope

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	7688	3 GENERATE	**1645.432**	1853.134	439.352	12.955	-0.610	-39.197
Min Fx	4734	3 GENERATE	**-1643.733**	1852.086	-438.837	-12.821	-0.595	38.863
Max Fy	1	3 GENERATE	-442.381	**1853.914**	-1645.521	-40.427	-0.622	8.240
Min Fy	8673	2 LL	55.926	**86.178**	-56.013	-1.261	-0.030	-1.428
Max Fz	6211	3 GENERATE	-438.330	1852.606	**1644.809**	39.136	-0.440	12.521
Min Fz	3	3 GENERATE	434.769	1852.466	**-1646.457**	-36.598	-4.204	-19.575
Max Mx	6703	3 GENERATE	442.830	1852.987	1644.270	**40.272**	-0.466	-8.682
Min Mx	1	3 GENERATE	-442.381	1853.914	-1645.521	**-40.427**	-0.622	8.240
Max My	6211	2 LL	-20.408	86.247	76.579	1.823	**-0.020**	0.583
Min My	3	3 GENERATE	434.769	1852.466	-1646.457	-36.598	**-4.204**	-19.575
Max Mz	5226	3 GENERATE	-1642.669	1851.954	442.103	8.484	-0.522	**40.016**
Min Mz	8180	3 GENERATE	1643.461	1852.355	-441.668	-8.227	-0.656	**-40.290**

E. Load Combinations

The following load combinations are defined for the analysis of structure which are:

1) Load Comb 3 Generated Indian Code Genral_Structures 1 1 1.5 2 1.5
2) Load Comb 4 Generated Indian Code Genral_Structures2 1 1.2 2 1.2
3) Load Comb 5 Generated Indian Code Genral_Structures3 1 1.5
4) Load Comb 6 Generated Indian Code Genral_Structures4 1 0.9

V. RESULTS AND DISCUSSIONS

In previous chapters, the discussion of maximum absolute plate pressure, maximum top principal major stress and minor stress. The description of each analysed structure, the loading applied, and the analysis procedures were also discussed in chapter 4. This chapter includes all the results carried out by the analysis. The results so obtained and compared in the form of plotted curves to present it in easier way along with discussions.

A. Maximum Corner Displacement Comparison

TABLE 3
PLATE CORNER DISPLACEMENTS FOR X, Y AND Z - DIRECTION (FOR PLATE NO. 921 TO 945)

Plate No.	Displacement			Plate No.	Displacement			Plate No.	Displacement		
	X (mm)	Y (mm)	Z(mm)		X (mm)	Y (mm)	Z(mm)		X (mm)	Y (mm)	Z(mm)
921	-0.28156	-0.79656	0.737254	922	-1.66453	-0.49503	0.178562	923	-3.89985	0.204656	-0.39207
	-1.66453	-0.49503	0.178562		-3.89985	0.204656	-0.39207		-5.87858	1.115256	-0.84652
	-1.29798	-0.02486	0.420341		-3.94477	0.886244	-0.08785		-6.50005	2.095642	-0.55124
	0	0	0		-1.29798	-0.02486	0.420341		-3.94477	0.886244	-0.08785
924	-5.87858	1.115256	-0.84652	925	-7.0209	1.802808	-1.14739	926	-7.17224	1.892002	-1.37331
	-7.0209	1.802808	-1.14739		-7.17224	1.892002	-1.37331		-6.47338	1.1556	-1.6246
	-8.04525	3.05067	-0.85577		-8.33151	3.276951	-1.07844		-7.53521	2.493098	-1.34342
	-6.50005	2.095642	-0.55124		-8.04525	3.05067	-0.85577		-8.33151	3.276951	-1.07844
927	-6.47338	1.1556	-1.6246	928	-5.23781	-0.43697	-1.97242	929	-3.83346	-2.71841	-2.43429
	-5.23781	-0.43697	-1.97242		-3.83346	-2.71841	-2.43429		-2.58419	-5.35881	-2.97144
	-6.06155	0.666299	-1.73813		-4.37689	-1.99352	-2.28109		-2.88227	-5.08548	-2.9215
	-7.53521	2.493098	-1.34342		-6.06155	0.666299	-1.73813		-4.37689	-1.99352	-2.28109
930	-2.58419	-5.35881	-2.97144	931	-1.69865	-7.93284	-3.50344	932	-1.23438	-10.0053	-3.9331
	-1.69865	-7.93284	-3.50344		-1.23438	-10.0053	-3.9331		-1.10189	-11.2199	-4.17515
	-1.83	-8.10113	-3.55891		-1.28692	-10.5259	-4.07471		-1.14251	-11.9402	-4.36536
	-2.88227	-5.08548	-2.9215		-1.83	-8.10113	-3.55891		-1.28692	-10.5259	-4.07471
933	-1.10189	-11.2199	-4.17515	934	-1.10442	-11.3714	-4.17998	935	-1.00396	-10.4477	-3.9475
	-1.10442	-11.3714	-4.17998		-1.00396	-10.4477	-3.9475		-0.59671	-8.63084	-3.52669
	-1.15886	-12.1032	-4.37125		-1.04899	-11.001	-4.09227		-0.56685	-8.84803	-3.58783
	-1.14251	-11.9402	-4.36536		-1.15886	-12.1032	-4.37125		-1.04899	-11.001	-4.09227
936	-0.59671	-8.63084	-3.52669	937	0.220285	-6.2575	-3.0014	938	1.407983	-3.7484	-2.46605
	0.220285	-6.2575	-3.0014		1.407983	-3.7484	-2.46605		2.779992	-1.52081	-1.99767
	0.412511	-6.04354	-2.96019		1.841083	-3.08964	-2.32579		3.487335	-0.48918	-1.78122
	-0.56685	-8.84803	-3.58783		0.412511	-6.04354	-2.96019		1.841083	-3.08964	-2.32579
939	2.779992	-1.52081	-1.99767	940	4.036656	0.097029	-1.63192	941	4.835143	0.932732	-1.35027
	4.036656	0.097029	-1.63192		4.835143	0.932732	-1.35027		4.886623	1.005926	-1.08469
	4.973717	1.357092	-1.37272		5.861997	2.237014	-1.07821		5.784649	2.179513	-0.81164
	3.487335	-0.48918	-1.78122		4.973717	1.357092	-1.37272		5.861997	2.237014	-1.07821
942	4.886623	1.005926	-1.08469	943	4.070987	0.525318	-0.7446	944	2.554831	-0.15924	-0.26836
	4.070987	0.525318	-0.7446		2.554831	-0.15924	-0.26836		0.905684	-0.64979	0.284692
	4.614442	1.457288	-0.46089		2.648205	0.52128	0.023136		0.789631	-0.13053	0.48769
	5.784649	2.179513	-0.81164		4.614442	1.457288	-0.46089		2.648205	0.52128	0.023136
945	0.905684	-0.64979	0.284692								
	0.174418	-0.79815	0.767036								
	0	0	0								
	0.789631	-0.13053	0.48769								

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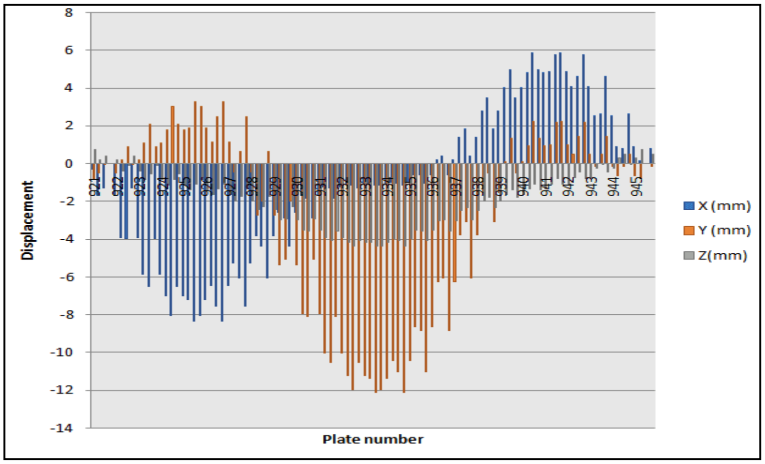


Graph 1 Plate Corner Displacements for X, Y and Z - Direction (For plate no. 921 to 945)

B. *Individual Plate Corner Displacement (For plate no. 9206)*

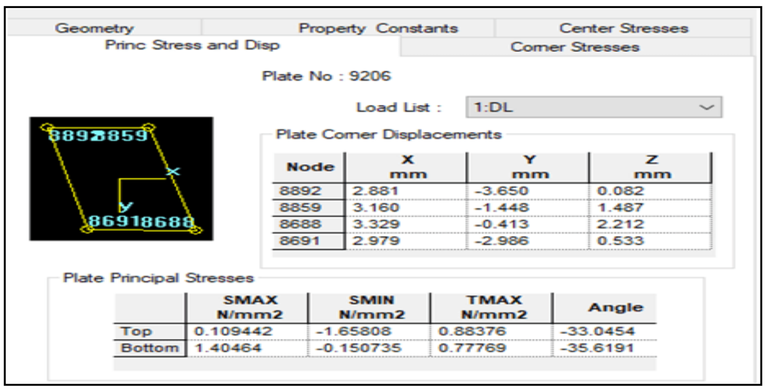
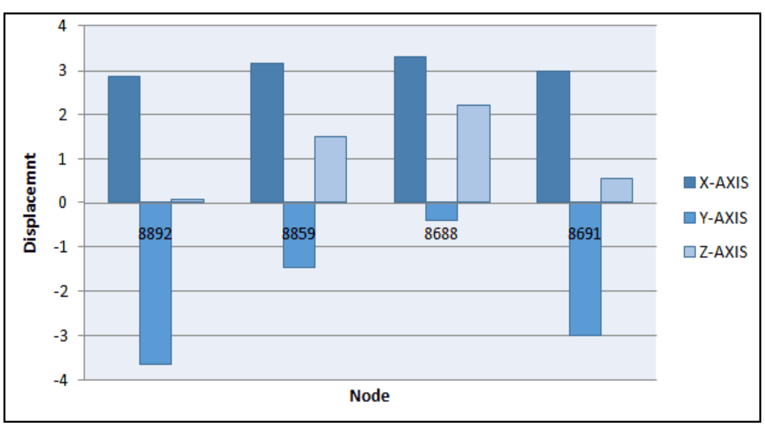


Fig.14 Plate corner displacement (For plate no. 9206)

TABLE 4
PLATE CORNER DISPLACEMENT (FOR PLATE NO. 9206)

Node	X-AXIS	Y-AXIS	Z-AXIS
8892	2.881	-3.65	0.082
8859	3.16	-1.448	1.487
8688	3.329	-0.413	2.212
8691	2.979	-2.986	0.533



Graph 2 Plate Corner Displacement (For plate no. 9206)

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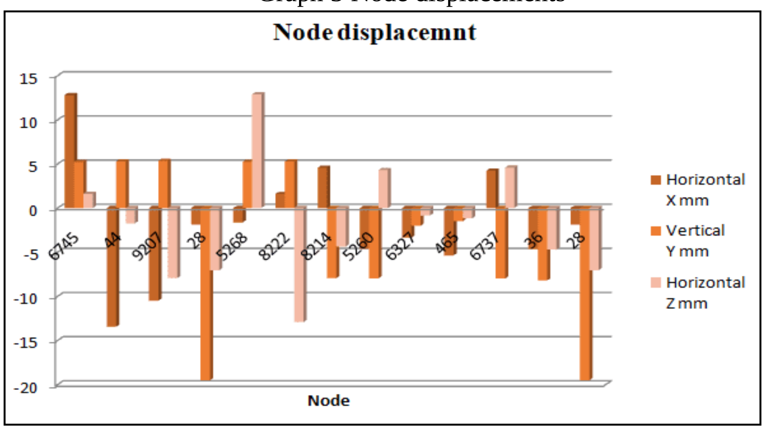
C. Maximum Node displacement

TABLE 5
NODE DISPLACEMENT (FOR PLATE NO. 9206)

All / Summary

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	6745	3 GENERATE	**12.792**	5.209	1.606	13.905	0.003	-0.002	0.001
Min X	44	3 GENERATE	**-13.435**	5.284	-1.739	14.542	-0.003	-0.002	-0.001
Max Y	9207	3 GENERATE	-10.494	**5.339**	-7.942	14.202	-0.002	-0.002	-0.002
Min Y	28	3 GENERATE	-1.869	**-19.518**	-7.049	20.836	0.002	-0.000	0.001
Max Z	5268	3 GENERATE	-1.643	5.251	**12.893**	14.018	-0.001	-0.002	0.003
Min Z	8222	3 GENERATE	1.594	5.271	**-12.932**	14.056	0.001	-0.002	-0.003
Max rX	8214	3 GENERATE	4.564	-7.929	-4.367	10.138	**0.007**	0.002	0.000
Min rX	5260	3 GENERATE	-4.642	-7.974	4.309	10.183	**-0.007**	0.002	-0.000
Max rY	6327	3 GENERATE	-3.365	-1.992	-0.848	4.001	0.001	**0.003**	0.005
Min rY	465	3 GENERATE	-5.371	-1.471	-1.150	5.686	-0.004	**-0.004**	0.005
Max rZ	6737	3 GENERATE	4.225	-7.988	4.589	10.135	-0.000	0.002	**0.007**
Min rZ	36	3 GENERATE	-4.648	-8.201	-4.711	10.538	0.000	0.002	**-0.007**
Max Rs	28	3 GENERATE	-1.869	-19.518	-7.049	**20.836**	0.002	-0.000	0.001

Graph 3 Node displacements



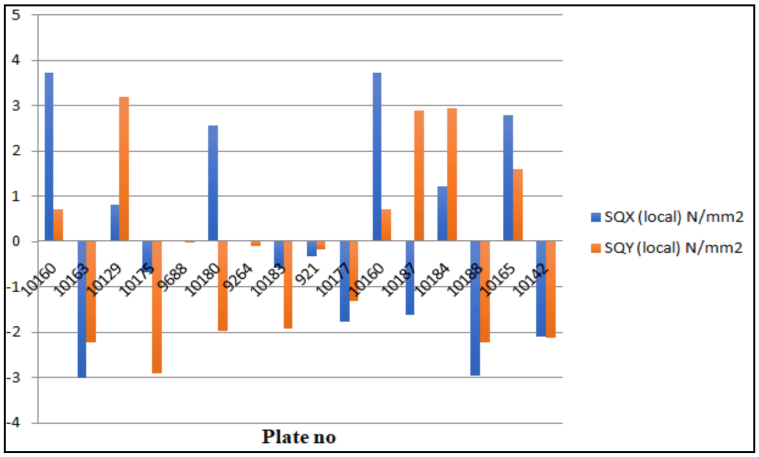
Graph 3 Node Displacement (For plate no. 9206)

D. Normal Stress, Circumferential & Longitudinal Stresses Comparison

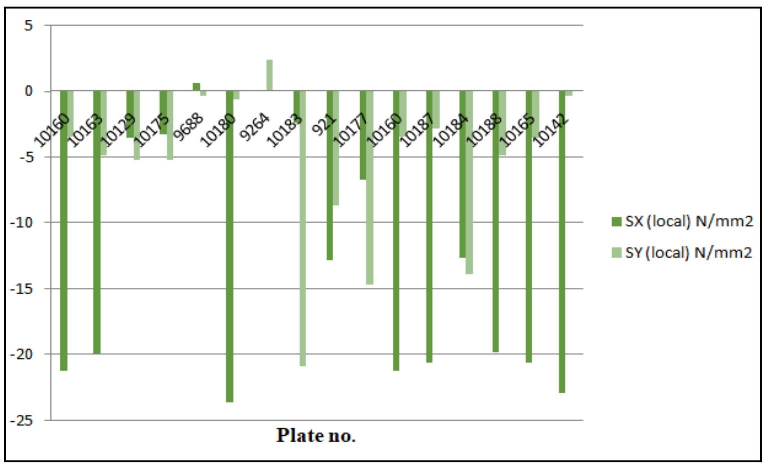
TABLE 6
NORMAL STRESS, CIRCUMFERENTIAL & LONGITUDINAL STRESSES BECAUSE OF APPLIED WEIGHT

Shear, Membrane and Bending / Summary / Principal and Von Mis / Summary / Global Moments / Co

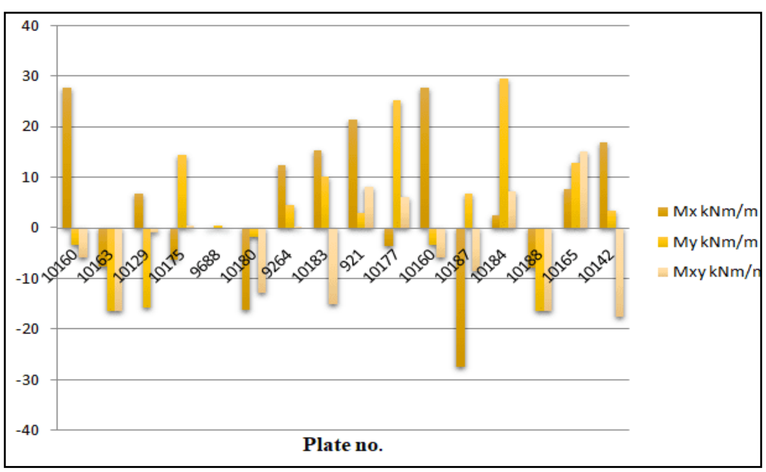
	Plate	L/C	Shear SQX (local) N/mm2	SQY (local) N/mm2	Membrane SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Bending Moment Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	10160	3 GENERATE	3.725	0.705	-21.289	-3.531	-6.517	27.685	-3.447	-5.857
Min Qx	10163	3 GENERATE	**-3.009**	-2.228	-19.978	-4.936	-8.103	-7.600	-16.423	-16.434
Max Qy	10129	3 GENERATE	0.802	**3.190**	-3.540	-5.294	-4.589	6.709	-15.644	-0.908
Min Qy	10175	3 GENERATE	-0.683	**-2.922**	-3.350	-5.231	-4.605	-6.292	14.331	0.371
Max Sx	9688	3 GENERATE	-0.000	-0.025	**0.616**	-0.387	-0.000	0.061	0.380	-0.002
Min Sx	10180	3 GENERATE	2.548	-1.986	**-23.683**	-0.688	-0.428	-16.188	-1.694	-12.887
Max Sy	9264	3 GENERATE	0.035	-0.101	0.066	**2.358**	-0.361	12.493	4.514	0.228
Min Sy	10183	3 GENERATE	-0.587	-1.927	-2.409	**-20.887**	5.450	15.339	10.048	-15.141
Max Sx	921	3 GENERATE	-0.339	-0.169	-12.878	-8.673	**8.641**	21.418	2.944	8.099
Min Sx	10177	3 GENERATE	-1.778	-1.314	-6.778	-14.760	**-10.560**	-3.519	25.246	6.045
Max Mx	10160	3 GENERATE	3.725	0.705	-21.289	-3.531	-6.517	**27.685**	-3.447	-5.857
Min Mx	10187	3 GENERATE	-1.630	2.883	-20.638	-2.838	6.939	**-27.456**	6.804	-8.450
Max My	10184	3 GENERATE	1.218	2.934	-12.684	-13.910	-9.876	2.522	**29.444**	7.137
Min My	10188	3 GENERATE	-2.973	-2.220	-19.891	-4.908	-8.051	-7.918	**-16.439**	-16.507
Max Mx	10165	3 GENERATE	2.772	1.605	-20.624	-3.607	-6.836	7.585	12.937	**15.109**
Min Mx	10142	3 GENERATE	-2.099	-2.127	-22.963	-0.409	0.810	17.012	3.337	**-17.483**



Graph 4 Shear in X and Y-direction



Graph 5 Circumferential Stresses



Graph 6 Bending Moment

A. Concrete Design

This RCC shell structure designed as per IS456-2000. In design we used M25 grade concrete and FE415 steel. Maximum longitudinal reinforcement at top and bottom is 824 mm^2 and 894 mm^2 respectively. Maximum transverse reinforcement at top and bottom 809 mm^2 and 497 mm^2.

Design element details are follow:

1) Total Number Of Plates - 5892
2) Plates In Dome – 144
3) Plates In One Ring - 483
4) Number Of Supports – 12

Results of different plates are vary and entire shell structure report is generated through staad, but we attaching design element 496 to 945 only.

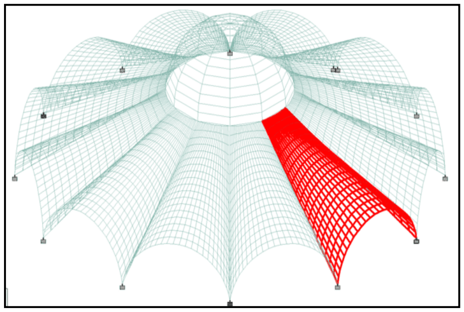


Fig.15 Design Element 496 to 945

B. Isolated Footing Design (IS456-2000)

TABLE 7
FOUNDATION GEOMETRY

Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
1	1	12.000 m	12.000 m	0.357 m
3	2	12.000 m	12.000 m	0.357 m
4242	3	12.000 m	12.000 m	0.357 m
4734	4	12.000 m	12.000 m	0.357 m
5226	5	12.000 m	12.000 m	0.357 m
5719	6	12.000 m	12.000 m	0.357 m
6211	7	12.000 m	12.000 m	0.357 m
6703	8	12.000 m	12.000 m	0.357 m
7196	9	12.000 m	12.000 m	0.357 m
7688	10	12.000 m	12.000 m	0.357 m
8180	11	12.000 m	12.000 m	0.357 m
8673	12	12.000 m	12.000 m	0.357 m

TABLE 8
FOOTING REINFORCEMENT & PEDESTAL REINFORCEMENT

Footing No.	Footing Reinforcement				Pedestal Reinforcement	
	Bottom Reinforcement (Mz)	Bottom Reinforcement (Mx)	Top Reinforcement (Mz)	Top Reinforcement (Mx)	Main Steel	Trans Steel
1	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
3	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
4242	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
4734	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
5226	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
5719	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
6211	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
6703	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
7196	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
7688	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
8180	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm
8673	Ø10 @ 55 mm c/c	Ø10 @ 55 mm c/c	Ø6 @ 75 mm c/c	Ø12 @ 65 mm c/c	12 - Ø10	Ø6 @ 160 mm

VI. CONCLUSION

Aim of the study is to designed of selected ''head cap'' shape shell structure which is used as business or commercial purpose having diameter of 50m and following conclusion has been drawn from the study:

1) Plate member is safe for dead and live load cases but with exception of seismic and combination of loads.
2) It is more durable, economical as it requires a minimum amount of material provides larger interior space and is exquisite. A shell dominantly behaves as a membrane, though, at the edges, bending stresses get concentrate.
3) The designed shell structure requires thickness of 120mm as compare other shapes that we have discussed in literature reviews. Below this thickness structure shows more overturning moment compare to resisting moment. Information has been collected about some shell structures that have been built so far.
4) Natural ventilation and Lightening used in the building. The structure of is very typical and complex. High standard of quality required at the time of construction.
5) The work is very innovational so the skills worker and labour used at the time of construction. The complete structure is both architecture and engineering point of view is Marvel.

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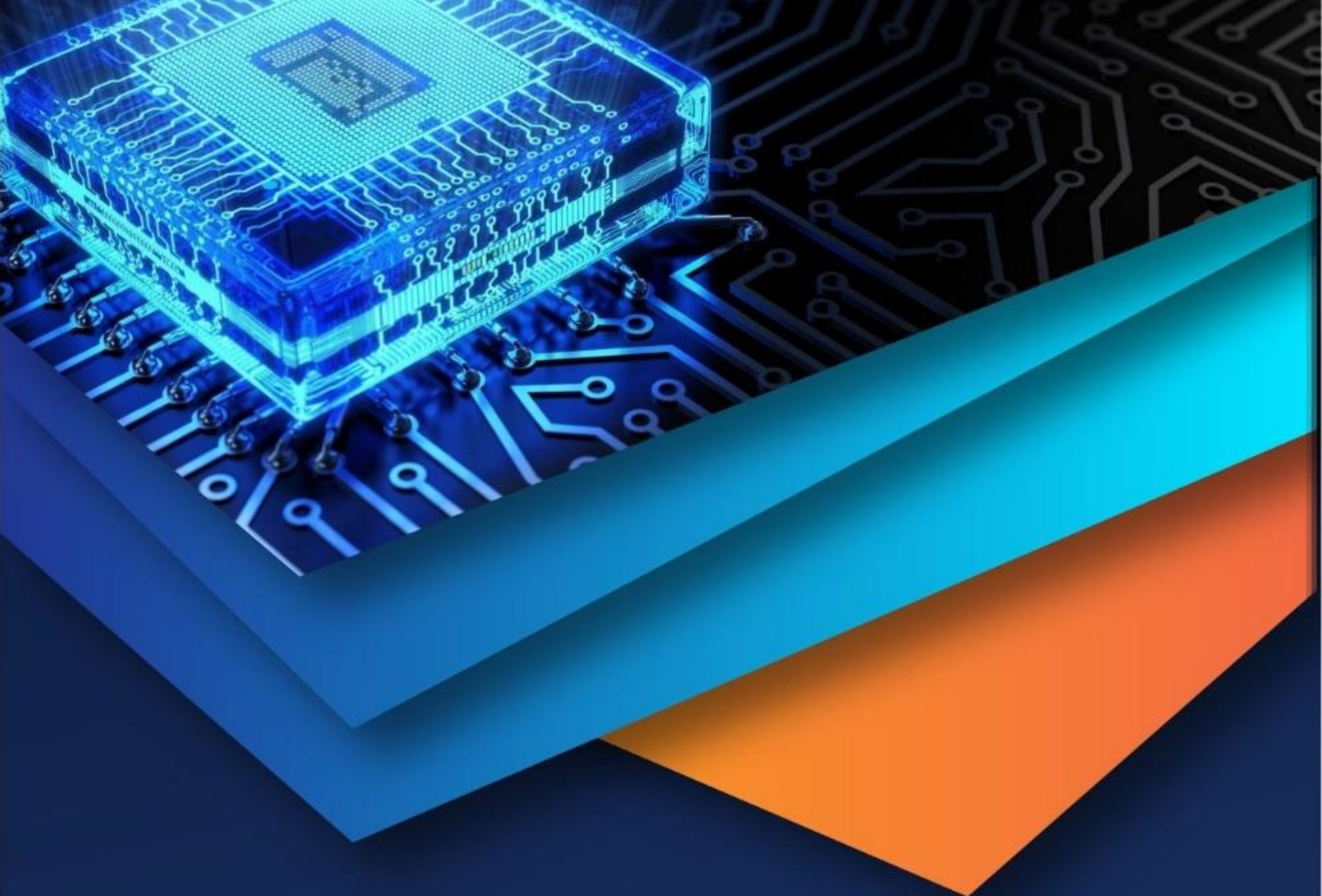

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