TEST Engineering & Management

May – June 2020
ISSN: 0193-4120 Page No. 9855 – 9858

Reinforced Cement Concrete cylindrical Shell for Parking Sheds

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Article Info
Volume 83
Page Number: 9855 – 9858
Publication Issue:
May - June 2020

Article History
Article Received*: 19 November 2019*
Revised*: 27 January 2020*
Accepted*: 24 February 2020*
Publication*: 18 May 2020*

Abstract:

The present reinforced concrete shells as a relevant and valuable structural solution. Shell structure are constructed from one or more curved slabs or folded plates. These are basically three-dimensional structures which are spatial in nature. The designers always aim to achieve economy by minimizing costs within the constraints of functional and aesthetic requirements. They thus try to choose a more relevant material which are cheaper and stronger or try to evolve new forms that resist the loads more efficiently. Off all one of the most efficient structural forms are shells and they are a perfect example of achieving strength through form as opposed to strength through mass. As we are trying to design efficient structure for parking space, we choose to design a reinforced concrete cylindrical shell. These concrete cylindrical shell structures allow area to be wide and to be spanned with no interior columns giving a good interior

Keywords: *cylindrical shell, end frames or traverses, interior columns, most efficient structural form.*

I. Introduction

Shell may be defined as the bidimensional curved element that has tendency to carry loads mainly in direct compression or tension rather than in bending and in shear. This definition implies that the thickness is small compared with its other dimensions, but it does not require that the smallness be extreme.

Shell roofs are preferable than plane roofs as they are used to cover large floor spaces with less use of materials. The use curved roofs require 25 to 40% less material than that of the plane elements. Structurally the shell roofs are superior since the whole cross-section is uniformly stressed due to the direct forces with negligible bending effects. Due to this the thickness of shell is usually very small in the range of 75 to 150 mm.

Shell roofs are generally adopted for hangers, sports auditorium, exhibition halls, industrial buildings and a variety other large span structures where uninterrupted floor span is required.

II. Literature Review

Shijo Jose – This study has investigated the fulfilled part of shell structures. They include the shells geometry, designing of shells, Classification of shells, costing, maintenance and many more.

V Sravana Jyothi – This study chose the topic of design and analysis of reinforced concrete shells. Shell concrete structures are been explained clearly. But the author should have chosen some images of shell structures.

Dr B H V Pal, B Durga Prasad Baliga - His study tells us about the economical design of single span long cylindrical shell roof with edge beam using the schooner theory.

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III. Design and analysis of cylindrical shell using beam theory

The following are the dimensions of a cylindrical shell:

Grade of concrete = 20mpa
Grade of steel = 415mpa
Radius of the shell = 8.6m
Central rise = 0.85m
Chord width = 6m
Span = 30m
Thickness of shell = 80m
Semi central angle = 40^o
Edge beam size = 230mm by 560mm
Area of steel in edge beam = 4 bars of 16 mm diameter
Width of edge beam = 230mm
Modular ratio = 10
Effective cover = 33mm
Live load = $1KN/m^2$

Let the neutral axis cut the shell at an angle α. Taking moments of effective areas about neutral axis, we have:

$2\,{}^{\alpha}\!\int_0 R.d\Theta.\,t\,(R\cos\Theta - R\cos\alpha) = m.\,2A_t\,(0.527 + R\cos\alpha - 2.75)$

Let m = 10, R = 3.6, $A_t = 4x\pi/4x16^2 = 804.24mm^2$

$R^2t(\sin\alpha - \alpha\cos\alpha) = m\,A_t(R\cos\alpha - 2.223)$

$3.6^2(0.08)\,(\sin\alpha - \alpha\cos\alpha) = 10 \times 804.24 \times 10^{-6}\,(3.6\cos\alpha - 2.223)$

$\alpha = 17^o$

$I_{NA} = 2\,{}^{\alpha}\!\int_0 R.d\Theta.t.R^2\,(\cos\Theta - \cos\alpha)^2 + m.2.A_t\,(0.527 + R\cos\Theta - 2.75)^2$

$= 1.477m^4$

Self-weight of shell = (0.08 x 25) = $1.92KN/m^2$
Live load = $1.00KN/m^2$
Total load = $2.92KN/m^2$

Total weight per meter run = $2\,{}^{40}\!\int_0 2.92\,(R.d\Theta)$ =40KN/m

Weight of edge beam = 2(0.23 x 0.56 x 25) = 6.44KN/m

Total load = 46.44KN/m

Maximum bending moment = $Wl^2/8 = (46.44 \times 30^2)/8$ = 5247KN/m

Maximum shear force = Wl/2 = (43.44 x30)/2 = 699.6KN

Maximum compressive stress at crown:

$\sigma_c = (M/I) \times y = (5247 \times 10^6 \times 160/ 1.477 \times 10^{12} = 0.568N/mm^2$

Maximum tensile stress at centre of gravity of steel is given by

$\sigma_t = (m \times \sigma_c \times y_1)/y_2 = (10 \times 0.568 \times 12.20)/160 = 43.3\ N/mm^2$

Shear stress $\tau = (V/IB) \times (Ay)$

$A\,.\,y = (4 \times \pi/4 \times 16^2 \times 10 \times 1220) = 9.81 \times 10^6\ mm^3$

Maximum horizontal shear stress at neutral axis

$\tau_y = (699.6 \times 10^3 \times 9.81 \times 10^6)/(1.447 \times 2 \times 80 \times 10^{12}) = 0.029N/mm^2$

Using 8 mm diameter bars inclined at 45^o to the longitudinal axis of the shell spacing is given by

$S_v = (\sqrt{2} \times \pi/4 \times 8^2 \times 230)/(80 \times 0.029) =$ 70.47mm near supports

Towards the center of span where span stress is less, adopt 6mm diameter bars at 7500mm center.

3.2 Design of short column

Load transmitted from one span of shell to columns = 1400KN

Factored load = 2800KN

Grade of steel (f_y) = 415mpa

Grade of concrete (f_{ck}) = 20mpa

Total load = 2000KN

From equation factored load P_u = 300KN

$P_u = 0.4\,f_{ck}\,A_c + 0.67 \times 415 \times 0.01\,A_g$

$P_u = 10.7\,A_g$

$A_g = 28037mm^2$

$A = B^2$

$B = \sqrt{A_g} = 167.44$; Take 230 mm

$A_{sc} = 0.01 \times 230 \times 230 = 529mm^2$

Adopt 4 number of 16 mm diameter rods

A_{sc} provided = $4 \times \pi \times 16^2 = 804.25mm^2 > A_{sc}$ required

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Design of transverse reinforcement: (≮grater of following)

i) (1/4) x 16 = 4mm
ii) 6mm

Let us provide 8mm diameter rods
Spacing (≯least of following)

i) 16 x16 = 256
ii) 230mm
iii) 300mm

Provide a spacing of 200mm

3.3 Design of footing

Load transmitted from the column to footing = 223.1KN

Calculation of Actual load:

P_u = 304.23KN; f_{ck} = 20N/mm^2; f_y = 410N/mm^2

P = P_u / 1.5 =304.23/1.5 = 202.82KN

10% of P = (10/100) x 202.82 = 20.38KN

P_t = 223.1KN

Calculation of area required:

$A_{required}$ = (p/q) = 223.1/400 = 0.56m^2

b/l = 230/230 = 1

B^2 = 0.56

B = 0.74m

$A_{provided}$ = 1.5 x1.5 = 2.25m^2 > 0.56m^2 (safe)

Calculation of bending moment:

M_{UB} = P_a x L x (B – b)^2/8 = 304.23/(1.5 x1.5) = 135.2 KM/m^2

M_{UB} = 135.2 x 500 x (1500 – 230)^2/8 = 40.89KN/m

Calculation of effective depth

M_{UB} = 0.138 f_{ck} x B x d^2

d = √ (40.89 x 10^6)/0.138x20x1500 =99.38mm

Hence D = 2 or 2.5d

D =2.5x 99.38 = 198.5mm

D = 200mm; d = 200 – 50 + 20/2 =160mm

Calculation of reinforcement

$$A_{st} = \frac{0.5 f_u}{f_y}\left(1-\sqrt{1-\frac{4\cdot 6}{f_{uk} L_d^2}}\right) Ld$$

= 767.08mm^2

$A_{st\ min}$ = (0.12/100) x L x D = (0.12/100) x 1500 x160 =288 mm^2

A_{st} > A_{min} (safe)

Check for one-way shear

V_{UB} = (P_a x L) ((B-b)/2 – d) = (135.2 x 1.5)((1.5-0.23)/2 – 0.16)

V_{UB} = 96.33KN

τ_{VL} = V_{UB} /B x d = 96.33 x 10^3 / 1500 x 60 = 0.39 =1mm^2

Calculate τ_c depends on

(100 x A_{st})/(B x d) = (100 x 767.03)/ (1500 x 160) =0.31

As per IS code 456:2000

T_c = 0.4 N/mm

τ_{VL} < τ_c (safe)

Check for two way shear

$$\tau_{developed} = \frac{P_a\left(LxB-(b+d)(l+d)\right)}{2[(b+d)+(l+d)]d} = \frac{135.2\ (1500x1500-(230+180)(230+160))}{2((230+160)+(230+160))x160x1000}$$

=1.1N/mm^2

τ_{dev} = 1.1N/mm^2

$\tau_{permissible}$ = $K_s\tau_c$

K_s = 0.5 + $ß_c$

$ß_c$ =b/l = 230/230 = 1

K_s = 0.5 + 1 = 1.5 ≯1

K_s =1

Check for load transfer

$f_{b\ developed}$ = P_u/(b x l) = 304.23/(230 x 230) = 5.75N/mm^2

$f_{permissible}$ =0.45 f_{ck} √(A_1/A_2)

A_1 = B x L = 1.5 x 1.5 = 2.25 m^2

A_2 = b x l = 0.23 x 0.23 =0.053m^2

√(A_1/A_2) = √(2.25/0.053) = 6.51 ≯ 2

$f_{s\ permissible}$ = 0.45 x 20 x 2 =18N/mm^2

f_{dev} < f_{perm} (safe)

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IV. Quantity Estimation of cylindrical shell

The quantity estimation is done by using center line method:

Table 1. Quantity estimation

Description of item	No's	Length (m)	Breadth (m)	Depth (m)	Quantity (m^3)	Total Quantity (m^3)
Excavation 2(28.5 +28.5)=174	1	174	1.5	0.2	52.2	52.2
Cement concrete for foundation	84	1.5	1.5	0.2	37.8	37.8
Cement concrete for column	84	0.23	0.23	2.19	9.73	9.73
cement concrete for slab 2(28.5 + 28.5)=114	2	114	30	0.08	547.2	547.7
Edge beam	12	30	0.23	0.56	46.368	46.368

V. Conclusion

We concluded that by comparing plane roofs and shell roofs. Shell roofs are preferable. shell theories are been explained by different theories they are Membrane theory, D.K.J theory and Beam theory

- RCC shell structure is more economical and has several advantages when compared to other structures
- Shell Terminology includes shell of revolution, shell of translation, Cylindrical shell, span of shell, chord width, Rise, beam and end frames.
- At last, we strongly conclude about the cost to design this structure. The designer always aims to achieve economy only by minimizing the costs. They always try use relevant materials that are cheaper yet strong

Scope for further work

- When the shell structures get damaged. They are some damage detection methods for shells that are used in present day work. In further days, these methods may be extended to examine the effectiveness of damage detection
- RCC shells mostly depends on the calculation and visualization of the shell structures

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