DESIGN OF AUTOMATED CIRCULAR PEDESTRIAN CROSSING AT A ROAD INTERSECTION

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Abstract - Automated circular pedestrian crossing (ACPC) is designed for pedestrians above a road/ railway, allowing them to reach either side in safety. The site selected for construction of Automated Circular Pedestrian Crossing is Rountana junction, Anna Nagar, Chennai where 2 mainroads intersect which comprises of schools, colleges, bus stops, metro station and shopping complexes. To make the pedestrian crossing effective mechanical components such as travellators and escalators are used. Architectural aspects are provided by using Glazed walls along the exterior and interior sides of the structure to get a topographical view of the area. The structure automated circular pedestrian crossing is an Iconic structure. The plan of structure was done by AUTO CADD and 3d models are rendered by using 3D'S MAX. The analysis of the structure is done by STAAD PRO

Keywords- automation, escalators, travellators, escalators, architectural aspects, iconic structure

1. INTRODUCTION

Pedestrian overpass comes under the four basic demands within every human life; there are food, cloth, house, and walk. Even in a developed city, walking is still an important facility of transport activities method, walking is the most basic human moving, thus, a complete and modern pedestrian overpass system in any city must be able to provide pedestrians with safety, comfort, quick and convenient across the road to their destination. A junction for instance, motorists and people driving cars and other locomotives find it very difficult to cross the signals due to excessive pedestrians crossing the road at the same time. Hence a number of accidents are encountered on a daily basis. To avoid this, an Automated Circular Pedestrian Crossing at such road junctions that might ease the pedestrians to cross the roads and help the motorists and other drivers to use the road harmoniously.Anescalator is a moving staircase, a conveyor transport device for carrying people between floors of a building. The device consists of a motor-driven chain of individual, linked steps that move up or down on tracks, allowing the step treads to remain horizontal. A moving walkway or moving sidewalk or travellator, is a slow-moving conveyor mechanism that transports people across a horizontal or inclined plane over a short to medium distance. Escalators and travellators are used around the world to move pedestrian traffic in places where elevators would be impractical. Principal areas of usage include department stores, shopping malls, airports, systems, convention centers, hotels, arenas, stadiums and public buildings.

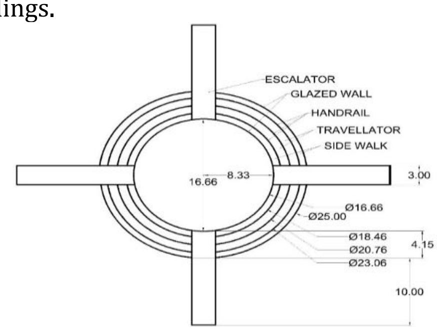

Fig. 1: Plan of the automated circular pedestrian crossing

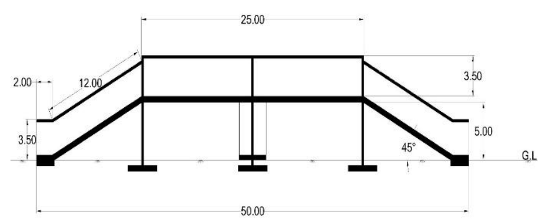

Fig. 2: Elevation of the automated circular pedestrian crossing

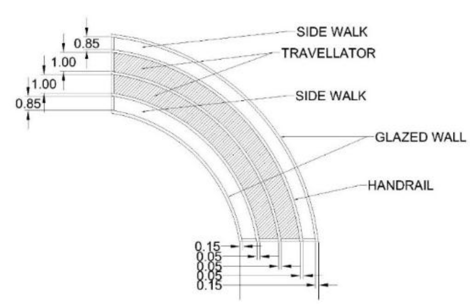

Fig. 3: Plan of the deck slab

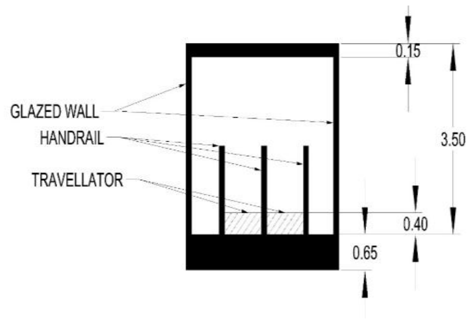

Fig. 3: Plan of the deck slab

2. DESIGN OF CIRCULAR SLAB WITH HOLE AT THE CENTER

Base slab diameter = 25 m
Centre hole diameter = 16.6 m
Live load = 5 kN/m²
f_{ck} = 25 N/ mm²
f_y = 415 N/ mm²
a = 12.5 m
b = 8.3m
R_u = 2.761
Effective depth of the slab
L/d = 20 , for simply supported one way slab
Code has not given any recommendation for circular slab
Assuming a factor 4/3 for circular one way slab
Assuming under reinforced structure
P_t = 0.2%
Modification factor = 1.68
And therefore, L/d = 20 x 4/3 x 1.63
= 44.8 = 45
Span/depth = 45
Depth = 25000/45
= 575
d = 580 mm
Cover = 20 mm
Therefore, overall depth
D = 580+20
= 600 mm

Load calculation
Self weight, DL = 0.6 x 25 x 1
= 15 kN/ m²
Live load, LL = 5 kN/ m²
Total load, TL = 20 kN/ m²
Factored load, UTL = 1.5 x 20
= 30 kN/ m²

Bending moment

Since this is a circular slab with center hole there are 2 moments to be found and they are,
Circumferential moment (M_θ)
Radial moment (M_r)

CIRCUMFERENTIAL MOMENT
W = 30 kN/ m²
a = 12.5 m
b = 8.33 m
RADIAL MOMENT
Since the maximum bending moment for simply supported section occurs at the mid span
r = 10.41 m
Therefore the moments,
M_θ = 889.15 KN-m
M_r = 87.258 KN-m

Check for depth

d = $\sqrt{\frac{Mu}{Ru \cdot b}}$
= 567.48
= 570 mm
Therefore, depth required < depth provided
Hence safe
Depth for circumferential reinforcement
= 600 – 20 - 8
= 572 mm
Depth for radial reinforcement
= 572 – 80 – 4
= 488 mm

Shear force

V = $\frac{wr}{2} - \frac{wb^2}{2r}$
Since shear force maximum at the outer edge of the slab for simply supported member
Therefore,
r = 12.57 mm
V = $\frac{30 \times 12.5}{2} - \frac{30 \times 8.33^2}{2 \times 12.5}$
= 104.23kN

Design of circumferential reinforcement $A_{st\theta} = \frac{0.5\,F_{ck}}{F_y}[\,1- \sqrt{1-\frac{4.6M_\theta}{F_{ck}\,b\,d_\theta^{\,2}}}\,]\,b\,d_\theta$

= 5046.66 mm²
No of bars = $\frac{A_{st\,\theta}}{a_{st}}$
Using 20 mm bars
No of bars = 16 bars
Spacing = $\frac{a_{st\,\theta}}{A_{st}} \times 1000$
= 120 mm
Provide 20 mm bars at 120 mm spacing c/c
Spacing increases from 120 mm to 300 mm

Design of radial reinforcement

$A_{st\theta} = \frac{0.5\,F_{ck}}{F_y}[\,1- \sqrt{1-\frac{4.6M_r}{F_{ck}\,b\,d_r^{\,2}}}\,]\,b\,d_r$
= 504.15 mm²
No of bars = $\frac{A_{st\,r}}{a_{st}}$

Using 10 mm bars
No of bars = 8 bars
Spacing = $\frac{a_{st}\, r}{A_{st}}\, x\ 1000$
= 100 mm
Provide 10 mm bars at 100 mm spacing c/c

Check for shear stress

τ_V = $\frac{V_u}{bd}$
= 0.18 N/mm²

$\tau_c = 0.3$ N/mm²
$k = 1$
Kτ_c= 0.31 N/mm²
K$\tau_c > \tau_c$, Hence safe against shear

3. DESIGN OF CIRCULAR BEAM

Load distribution from slab to beam

Which is given by = 30 x 4.17
= 120.16 kN/m
Load on one beam = 120.16/2
= 60.8 kN/m

Data obtained

Span l = 19.6 m
Imposed load = 60.8 kN/m
F_{ck} = 25 N/ mm²
F_y = 415 N/ mm²

Depth

$\frac{span}{depth}$ = 45
Depth = 19600/45
= 450 mm
Provide cover = 20 mm
Overall depth = 450+20
= 470 mm
Effective span = clear span + effective depth
= 19.6 + 0.45
= 20 m

Load calculation

Dead load, DL = 0.23x0.47x25
= 2.3 kN/m
Factored DL = 1.5 x 2.3
= 3.45 kN/m
θ = 0.785 radians

Maximum bending moment

BM = $W_u R^2 [\frac{\theta}{SIN\theta} COS\emptyset - 1]$

Bending moment is max at the centre for simply supported, at centre $\emptyset = 0$
= 1110.32 kN-m

Maximum shear force

SF = $W_u R\emptyset$

Shear force is maximum at the supports for simply supported,
At support $\emptyset = \theta$
= 64.25x12.5x0.785
= 630.45 Kn

Maximum torsion

$T_U = W_u R^2 \left[\frac{\theta}{sin\theta} \sin\emptyset_m - \emptyset_m\right]$

$\emptyset_m = \cos^{-1}[\frac{\sin\theta}{\theta}]$

$= cos^{-1}[\frac{sin0.785}{0.785}]$
= 332 kN

Check for depth

$M_u = 0.138\ F_{ck} bd^2$

d = $\sqrt{\frac{Mu}{0.138\ F_{CK}\, b}}$
= $\sqrt{\frac{1110.32X\ 10^6}{0.138\ X\ 25\ X\ 10^3}}$
= 43 2 mm
= 440 mm < 450 mm

Hence it's safe

Area of reinforcement

$M_u = 0.87\ f_y A_{st}\, d\left[1 - \left(\frac{f_y A_{st}}{bd\, f_{ck}}\right)\right]$

A_{st} = 6903.4 mm²

Provide 8 no bars of 20 mm at 125 mm spacing c/c

Check for shear stress

$\tau_v = \frac{V_u}{b\ d}$

V_u = $W_u R\emptyset$
= $W_u R(\theta - \emptyset_m)$
= 269.05 kN

Therefore,

τ_v = $\frac{269.05\ X\ 10^3}{10^3\ X\ 550}$
= 0.49 N/mm²

p_t = $\frac{100\ A_{st}\ l}{b\ d}$
= 0.89 N/mm²

K = 1.3
Kτ_c = 1.3 x 0.89
= 1.16 N/mm^2

$\tau_v <$ Kτ_c

Hence the shear stress is within permissible limit

Check for torsion

$\tau_{ve} = V_u + 1.6\frac{T_u}{b}$
= 270 N/mm^2

$\tau_{ve} > \tau_c$

Hence the torsion is within permissible limit

4. DESIGN OF PIER CAP

Bearing length

BL = 640 mm

Bearing strength

BS = 0.8 f_{ck}

= 0.8 x 25

= 20 N/mm²

Width of the bearing plate = $\frac{f_v}{BL\ X\ BS}$

= $\frac{1260\ X10^3}{640\ X\ 20}$

Calculated width = 94.43 mm

As corbel is an isolated member, increase the width by 20 mm

= 95+20

= 115

Adopt a bearing plate of 1500 x 120 mm

Depth

D = $\frac{1260\ X10^3}{640\ X\ \tau_{c\,max}}$

= $\frac{1260\ X10^3}{640\ X\ 3.5}$

= 520 mm

Overall depth D_s = d + cover

= 520 + 20 + 20/2

= 550 mm

Depth at the face D_r = D/2

= 550/2

= 275 mm

Check for the struct action

= $\frac{a_v}{d}$

= $\frac{300}{550}$

= 0.55

Determination of lever arm

= $\frac{f_v}{f_{ck}bd}$

= $\frac{1260\ x\ 10^3}{25\ X\ 640\ X\ 520}$

= 0.15

$\frac{z}{d}$ = **0**.68

Z = 0.68 x 520

= 353.6 mm = 355 mm

X = 2.22 (d-z)

=2.22 (520 – 355)

= 366.3 mm

= 365 mm

$\frac{x}{d}$ = $\frac{365}{520}$

= 0.7

Resolution of forces

$F_t = \frac{f_v a_v}{z}$

= $\frac{1260\ X\ 300}{355}$

= 1064.78 kN

Reinforcement area

$A_{st} = \frac{f_t + f_h}{f_s}$

To find f_s , we have to find ε_s

$\varepsilon_s = \frac{0.035(d-x)}{x}$

= $\frac{0.035\ (\ 520 - 365)}{365}$

= 0.014

For ε_s = 0.014, $f_s = 280$ N/mm²

$therefore$ A_{st} = $\frac{1065\ X\ 10^3\ +0}{280}$

= 3803.5 mm²

= 3800 mm²

Use 12 no of 20 mm dia bars

Check for max & min steel

= $\frac{100A_{st}}{bd}$

= 1.14

Area of shear steel A_{sw} = $\frac{A_{st}}{2}$

= $\frac{3800}{2}$

= 1900 mm²

Provide 8 no of 12 mm links 2 legged in the upper 2/3rd depth of the pier cap

Spacing = $\frac{2}{3} X \frac{d}{no\ of\ links}$

= 120 mm

Shear capacity of the section

$\tau_c = \frac{100A_s}{bd}$

= 0.682

Increased shear strength τ_m = $\tau_c \frac{2d}{a_v}$

= 2.36 N/mm²

Shear capacity of concrete = $\frac{\tau_m\ X\ bd}{1000}$

= 785 kN

Shear capacity of steel = $\frac{0.87\ X\ f_y A_{st} d}{s_v}$

= 523.15 kN

Total shear capacity = 1308.15 Kn

< 1260 kN

Hence it's safe

5. DESIGN OF PIER

Axial load on the column = 2600 kN

Length of the column l = 5 m

Effective length l_e = 5 m

Let us use 1% steel

Assuming the $e_{min} \leq 0.05$ D

Assume B=D/2

Gross area

$p_u = 0.4\, f_{ck} A_c + 0.67\, f_y A_{sc}$

A_g = 205031.15 mm²

BD = 205031.15 mm²

$\frac{1}{2}$DD = 205031.15 mm²

D = 640 mm

B = 320 mm

Reinforcement area

A_s = 0.01x205031.1

= 2050.31 mm²

No of bars = $\frac{2050.31}{(\frac{\pi}{4}20^2)}$

= 12 bars

% of steel = $\frac{2413.2}{320 \times 640}$

= 0.89%

Check for load capacity of the column

Check for slenderness ratio

$\frac{L}{D}$ = $\frac{5000}{640}$

= 7.8 < 12

Hence column is a short column

Check for eccentricity

$e_{min} = \frac{L}{500} + \frac{D}{30}$

= $\frac{5000}{500} + \frac{640}{30}$

= 10 + 21

= 31 mm

0.05D = 0.05 x 640

= 32mm

$e_{min} < 0.05\, D$

Hence the column is safe

6. DESIGN OF FOOTING

Size of the column = 320mmx640mm

Imposed load = 2600 kN

Soil bearing capacity q_s = 200 kN/m²

Factored soil bearing capacity

= 1.5x 200 kN/m²

= 300 kN/m²

Size of footing

Load on column = 2600 kN

Assume Self weight is ignored

Total factored Load, $w_u = 2600$ kN

Footing area = $\frac{2600}{300}$

= 11.56

= 12 m²

Footing proportioned approximately in the same proportion as that of the column side

(3.2A) (6.4A) = 12

A = 0.77

Short side of the footing = 3.2 A

= 3.2 x 0.77

= 2.5 m

Long side of the footing = 6.4 A

= 6.4 x 0.77

= 5 m

Factored soil pressure ,q_u = $\frac{2600}{2.5 \times 5}$

= 208 KN/m²

= 208 KN/m²

< 300 KN/m²

Hence the footing area is adequate since the soil pressure developed at the base is less than the factored bearing capacity of the soil.

Factored bending moment

Cantilever projection from theshort side face of the footing

= 0.5 (5 - 0.64)

= 2.18 m

Cantilever projection from thelong side face of the footing

= 0.5 (2.5 - 0.32)

= 1.09 m

Bending moment at long side Face of the column

$= \frac{q_u \times l_y^2}{2} = \frac{208 \times 2.18^2}{2}$

= 494.25 KN-m

Bending moment at short sideFace of the column

$= \frac{q_u \times l_x^2}{2}$

= 123.56 KN-m

Depth of footing

From moment consideration

$M_u = 0.138 f_{ck} bd^2$

d = 378.49

= 400 mm

From shear stress consideration

For one way shear the critical section is located at a distance d from the face of the column

Shear force per meter width

$V_{uL} = q_u \left(\frac{L}{2} - \frac{640}{2} - d\right)$

= 208(2180 – d)

Assuming shear strength τ_c = 0.36 N/mm^2 for M25 concrete with nominal percentage of steel, p = 0.25

$\tau_c = \frac{V_{uL}}{bd}$

d = 356.54

= 360 mm

Overall depth = 400 mm

Reinforcement area

Longer direction

$$M_u = 0.87\, f_y A_{st}\, d\left[1 - \left(\frac{f_y A_{st}}{bd\, f_{ck}}\right)\right]$$

A_{st} = 4916.54 mm²

No of bars = $\frac{4916.54}{\frac{\pi}{4} X\, 20^2}$

= 13 bars

Spacing = 100 mm

Provide 20 mm diameter bars at 100 mm spacing

Shorter direction

$$M_u = 0.87\, f_y A_{st}\, d\left[1 - \left(\frac{f_y A_{st}}{bd\, f_{ck}}\right)\right]$$

A_{st} = 996.37 mm²

No of bars = $\frac{996.37}{\frac{\pi}{4} X\, 20^2}$

= 4 bars

Spacing = 100 mm

provide 20 mm diameter bars at 250 mm spacing

Central band

Central band width = width of footing = 2.5 m

$= \frac{2}{\beta + 1}$

$$\beta = \frac{5}{2.5} = 2$$

Reinforcement in the central band Of 2.5m

$= \frac{2}{2.5+1}$ x 996.37 x2.5

$(A_{st})_{cb}$ = 1423.39 mm²

Minimum reinforcement = 0.0012 x 1000 x 400

= 960 mm²

$<$ 1423.39 mm²

Hence provide 16 mm dia bars at 110 mm c/c

Check for shear stress

Critical section for one way shear is located at a distance d from the face of the column

Ultimate shear force per meter width ,In the longer direction

$V_{UL} = 208(2180 - 360)/10^3$

= 378.56 kN

= 0.98

$K_S \tau_C = 1$ x 0.96

= 0.96

Nominal shear stress, $\tau_v = \frac{V_u}{b\, d}$

$= \frac{378.56 \; X \; 10^3}{10^3 \; X \; 360}$

= 0.89 N/mm²

$k\tau_C > \tau_v$ Hence safe against shear

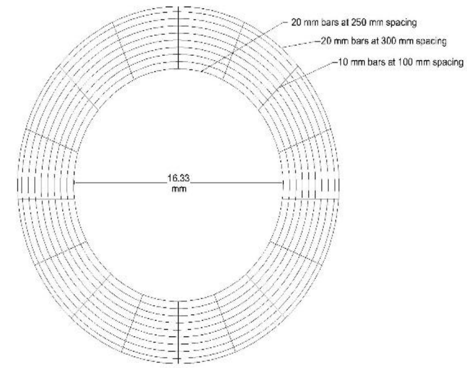

Fig. 4: Reinforcement details of circular slab with hole at the center

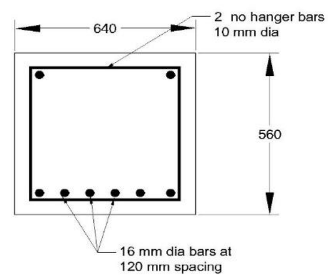

Fig. 5: Reinforcement details of circular beam

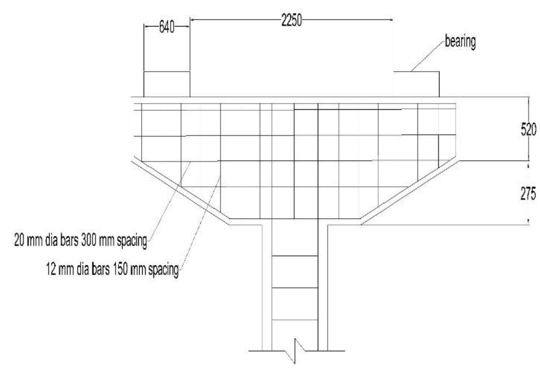

Fig. 6: Reinforcement details of pier cap

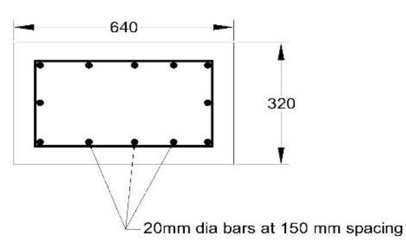

Fig. 6: Reinforcement details of pier

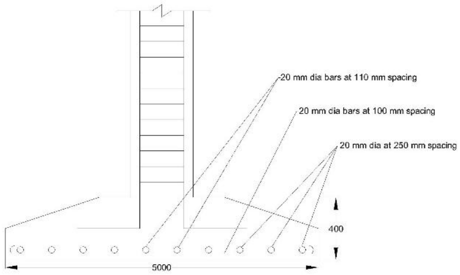

Fig. 7: Reinforcement details of footing

8. STAAD PRO RESULT

The result obtained from the staad pro are **BENDING MOMENT**

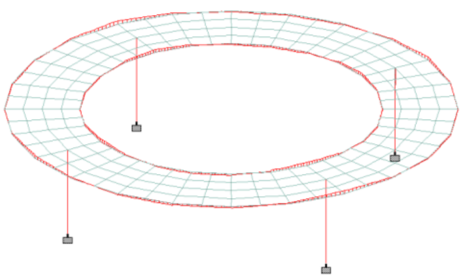

Fig. 8: Bending moment due to dead load

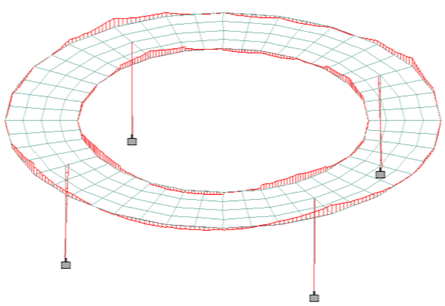

Fig. 9:Bending moment due to live load

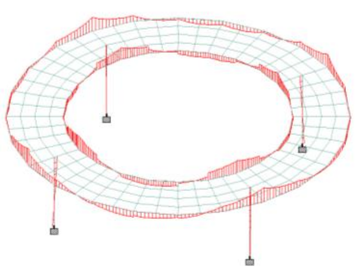

Fig. 10:Bending moment due to load combination

SHEAR FORCE

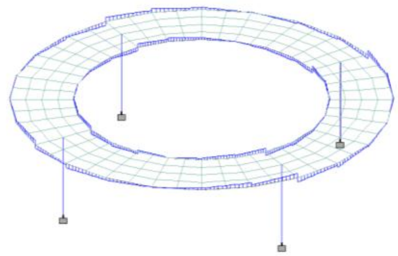

Fig. 11:Shear force due to dead load

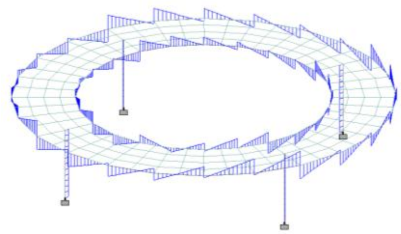

Fig. 12:Shear force due to dead load

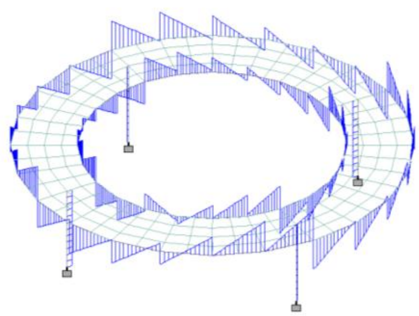

Fig. 13:Shear force due to dead load

3D MODELS

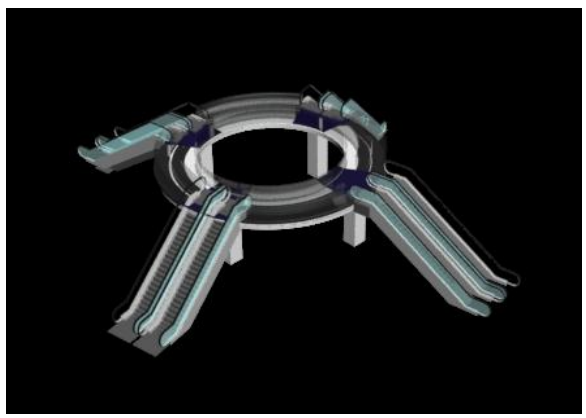

Fig 14: Projected appearance of the automated circular pedestrian crossing without ceiling and glazed wall

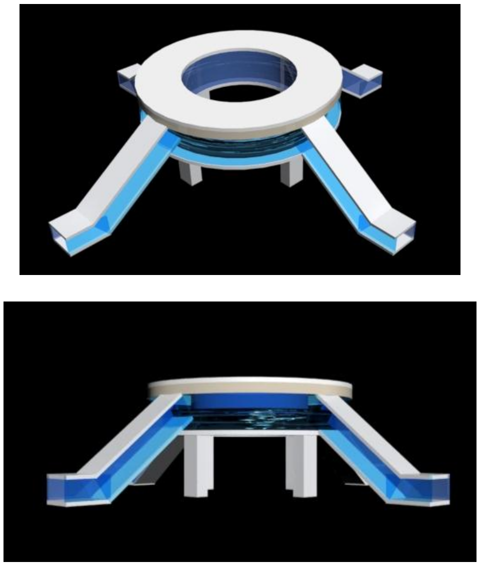

Fig 15: Projected appearance of the automated circular pedestrian crossing with ceiling and glazed wall

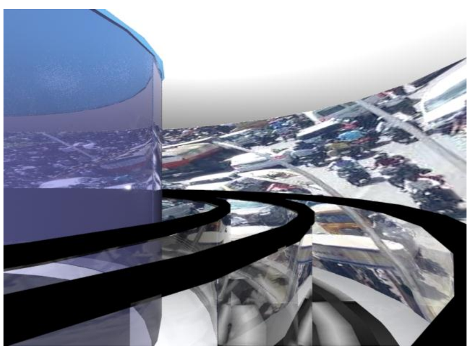

Fig 16: Interior of the structure

8. RESULT

Component	Bending moment	Shear force	Reinforcement Details
Circular slab	M_θ = 889.15 kN-m M_r = 87.258 kN-m	104.23 kN	20 mm dia bars at 120 mm spacing c/c 10 mm dia bars at 100 mm spacing c/c
Circular beam	M = 1110.32 kN-m	630.45 kN	20 mm dia bars at 125 mm spacing c/c
Pier cap	-	1260 kN	20 mm dia bars at 300 mm spacing c/c
Pier	-	2600kN	20 mm dia bars at 150 mm spacing c/c
Footing	M = 494.25 kN-m M = 123.56 kN-m	378.56 kN	20 mm dia bars at 250 mm spacing c/c 20 mm dia bars at 110 mm spacing c/c

8. CONCLUSION

The Pedestrian Overpass a road intersection has been designed to be structurally stable and safe against failure. It has been designed to look aesthetically appealing and to be an iconic structure in the city. The Construction of the Pedestrian Overpass Access would reduce the commotion at the proposed location thereby enabling the pedestrians to cross the junction with ease and safety. The alignment also enables the crossing the roads quickly thereby saving time. The additional components and features are made to make this structure unique and iconic. Due to the construction of this pedestrian crossing the vehicular traffic remains undisturbed and The entire design of various components of the Pedestrian Overpass, with all necessary checks has been done. The project served to be a complete revision of the reinforced concrete design of various structural components. It led to better understanding of our potentials and enhancement of a positive approach towards anything we take up.

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