DESIGN OF AUTOMATED CIRCULAR PEDESTRIAN CROSSING AT A ROAD INTERSECTION

B. Magesh¹, P.K. Ajith², R. Akaash³, S Ben Jachin ⁴

¹Assistant Professor, Department of Civil Engineering, PERI Institute of Technology, Chennai 48.
²,³,⁴Student, Department of Civil Engineering, PERI Institute of Technology, Chennai 48

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 main roads 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 CAD and 3d models are rendered by using 3D'S MAX. The analysis of the structure is done by STAAD PRO.

Keywords- automation, escalators, travellators, 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. An escalator 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.
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 = 8.3 m  
$R_u$ = 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, $L/d = 20 \times 4/3 \times 1.63$
= 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 ($M_\theta$)
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,
$M_\theta$ = 889.15 KN-m  
$M_r$ = 87.258 KN-m

Check for depth
$d$ = $\sqrt{\frac{M_r}{R_u \cdot b}}$
= 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
$V = \frac{W (a \times b)}{2 \times r}$
Since shear force maximum at the outer edge of the slab for simply supported member
Therefore,
$r$ = 12.57 mm
$V = \frac{30 \times 12.5 \times 10 \times 8.33}{2 \times 2 \times 12.5}$
= 104.23kN

Design of circumferential reinforcement
$A_{st \theta} = \frac{0.5 \cdot f_{ck} \cdot b \cdot d_{\theta}}{f_y \cdot \left(1 - \frac{4.6M_\theta}{f_{ck} \cdot b \cdot d_{\theta}}\right)}$
= 5046.66 mm²

No of bars = $\frac{A_{st \theta}}{a_{st \theta}}$
Using 20 mm bars
No of bars = 16 bars
Spacing = $\frac{600}{120} \times 1000$
= 120 mm

Provide 20 mm bars at 120 mm spacing c/c
Spacing increases from 120 mm to 300 mm

Design of radial reinforcement
$A_{st \theta} = \frac{0.5 \cdot f_{ck} \cdot b \cdot d_{\theta}}{f_y \cdot \left(1 - \frac{4.6M_\theta}{f_{ck} \cdot b \cdot d_{\theta}}\right)}$
= 504.15 mm²

No of bars = $\frac{A_{st \theta \theta}}{a_{st \theta}}$
Using 10 mm bars
No of bars = 8 bars
Spacing = \( \frac{64 \times 1000}{25} \) = 100 mm
Provide 10 mm bars at 100 mm spacing c/c

Check for shear stress
\[ \tau_c = 0.3 \text{ N/mm}^2 \]

K1 = 1
K2 = 0.31 N/mm²
K1K2 > \tau_c, Hence safe against shear

3. DESIGN OF CIRCULAR BEAM

Load distribution from slab to beam
Which is given by
\[ \text{Load on one beam} = \frac{120.16 \text{ kN/m}}{2} = 60.8 \text{ kN/m} \]

Data obtained
Span l = 19.6 m
Imposed load = 60.8 kN/m

Fck = 25 N/mm²
Fy = 415 N/mm²

Depth
\[ \text{span depth} = 45 \]

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
\[ \theta = 0.785 \text{ radians} \]

Maximum bending moment
\[ BM = W_u R^2 \left[ \frac{\theta}{u \pi} \cos \theta - 1 \right] \]
Bending moment is max at the centre for simply supported, at centre \( \theta = 0 \)
\[ = 1110.32 \text{ kN-m} \]

Maximum shear force
\[ SF = W_u R \theta \]

Shear force is maximum at the supports for simply supported,
At support \( \theta = \theta \)
\[ = 64.25 \times 12.5 \times 0.785 = 630.45 \text{ kN} \]

Maximum torsion
\[ T_u = W_u R^2 \left[ \frac{\theta}{u \pi} \sin \theta m - \phi_m \right] \]
\[ \phi_m = \cos^{-1} \left[ \frac{\sin \theta}{\theta} \right] \]
\[ = \cos^{-1} \left[ \frac{\sin \theta}{\theta} \right] \]
\[ = 332 \text{ kN} \]

Check for depth
\[ M_u = 0.138 F_{ck} bd^2 \]
\[ d = \sqrt{\frac{M_u}{0.138 F_{ck} b^2}} \]
\[ = \sqrt{\frac{1110.32 \times 10^6}{0.138 \times 25 \times 10^3}} = 43.2 \text{ mm} \]
\[ = 440 \text{ mm} < 450 \text{ mm} \]

Hence it's safe

Area of reinforcement
\[ M_u = 0.87 f_y A_{st} \left[ 1 - \left( \frac{f_{st}}{f_y} \right) \right] \]
\[ A_{st} = 6903.4 \text{ mm}² \]
Provide 8 no bars of 20 mm at 125 mm spacing c/c

Check for shear stress
\[ \tau_u = \frac{V_u}{b d} \]
\[ V_u = W_u R \theta \]
\[ = W_u R (\theta - \phi_m) \]
\[ = 269.05 \text{ kN} \]

Therefore,
\[ \tau_u = \frac{269.05 \times 10^3}{10^3 \times 550} = 0.49 \text{ N/mm}^2 \]
\[ P_t = \frac{100 \times f_{st}}{b d} \]
\[ = 0.89 \text{ N/mm}^2 \]
K = 1.3
K2 = 1.3 x 0.89
\[ = 1.16 \text{ N/mm}^2 \]

\[ \tau_u < K2 \]
Hence the shear stress is within permissible limit

Check for torsion
\[ \tau_{ug} = V_u + 1.6 \tau_u \]
\[ = 270 \text{ N/mm}^2 \]
\[ \tau_{ug} > \tau_c \]

Hence the torsion is within permissible limit
4. DESIGN OF PIER CAP

**Bearing length**

\[ BL = 640 \text{ mm} \]

**Bearing strength**

\[ BS = 0.8 f_{ek} = 0.8 \times 25 = 20 \text{ N/mm}^2 \]

**Width of the bearing plate**

\[ W = \frac{f_s}{BL \times BS} \]

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**

\[ D = \frac{1260 \times 10^3}{640 \times 20} = 520 \text{ mm} \]

Overall depth \( D_s \)

\[ D_s = d + \text{cover} = 520 + 20 + 20/2 = 550 \text{ mm} \]

Depth at the face \( D_f \)

\[ D_f = D/2 = 550/2 = 275 \text{ mm} \]

**Check for the structure action**

\[ \varepsilon_s = \frac{0.025 (d - x)}{x} \]

\[ \varepsilon_s = \frac{0.025 (520 - 355)}{355} = 0.014 \]

For \( \varepsilon_s = 0.014, f_s = 280 \text{ N/mm}^2 \)

Therefore \[ A_{st} = \frac{1065 \times 10^3 + 0}{280} = 3803.5 \text{ mm}^2 \]

= 3800 \text{ mm}^2

Use 12 no of 20 mm dia bars

**Check for max & min steel**

**Resolution of forces**

\[ F_r = \frac{f_s a_v}{z} \]

**Reinforcement area**

\[ A_{st} = \frac{f_s + f_a}{f_s} \]

}\n
\[ d = 20 \text{ mm} \]

\[ B = D/2 \]

5. DESIGN OF PIER

**Axial load on the column** = 2600 kN

**Length of the column** \( l = 5 \text{ m} \)

**Effective length** \( l_e = 5 \text{ m} \)

Let us use 1% steel

Assuming the \( e_{min} \leq 0.05D \)

Assume B = D/2

\[ 520 \]

**Shear capacity of the section**

\[ \tau_c = \frac{100 A_f}{b d} \]

\[ \tau_c = \frac{100 \times 520}{3800} = 0.682 \]

**Increased shear strength** \( \tau_m = \tau_c \frac{2d}{a_v} \)

\[ \tau_m = \frac{2.36 \text{ N/mm}^2}{0.682} = 3.48 \text{ N/mm}^2 \]

**Shear capacity of concrete**

\[ \tau_m x b d = 785 \text{ kN} \]

**Shear capacity of steel**

\[ \frac{87 \times f_y A_{st} d}{1000} = 523.15 \text{ kN} \]

**Total shear capacity**

\[ < 1308.15 \text{ kN} \]

Hence it's safe
Gross area
\[ A_g = 0.4 f_{ck} A_c + 0.67 f_y A_{sc} \]
\[ A_g = 205031.15 \text{ mm}^2 \]
BD = 205031.15 \text{ mm}^2
\[ \frac{D}{2} = 205031.15 \text{ mm}^2 \]
D = 640 mm
B = 320 mm

Reinforcement area
\[ A_z = 0.01x205031.1 \]
\[ A_z = 2050.31 \text{ mm}^2 \]

No of bars
\[ \frac{2050}{640} \]
\[ = 12 \text{ bars} \]

% of steel
\[ \frac{640 \times 640}{2 \times 205031.15} \]
\[ = 0.89\% \]

Check for load capacity of the column
Check for slenderness ratio
\[ \frac{L}{D} = 5000 \]
\[ = 78 < 12 \]

Hence column is a short column

Check for eccentricity
\[ e_{min} = \frac{L}{500} + \frac{D}{2b} \]
\[ e_{min} = \frac{5000}{500} + \frac{640}{32} \]
\[ = 10 + 21 \]
\[ = 31 \text{ mm} \]
\[ 0.05D = 0.05 \times 640 \]
\[ = 32 \text{ mm} \]
\[ e_{min} < 0.05D \]

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
\[ = 1.5 \times 200 \text{ kN/m}^2 \]
\[ = 300 \text{ kN/m}^2 \]

Depth of footing
From moment consideration
\[ M_u = 0.138 f_{ck} b d^2 \]
\[ d = 378.49 \]
\[ = 400 \text{ mm} \]

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 \( f_c = 0.36 \text{ N/mm}^2 \) for M25 concrete with nominal percentage of steel, \( p = 0.25 \)
\[ f_c = \frac{V_{ul}}{d b} \]
\[ d = 356.54 \]
\[ = 360 \text{ mm} \]
Overall depth = 400 mm

Reinforcement area

Longer direction
Central band

Central band width = width of footing = 2.5 m
\[ \beta = \frac{5}{2.5} = 2 \]
Reinforcement in the central band Of 2.5 m
\[ (A_{et})_{cb} = \frac{2}{2.5+1} \times 996.37 \times 2.5 = 1423.39 \text{ mm}^2 \]
Minimum reinforcement = 0.0012 x 1000 x 400
\[ = 960 \text{ mm}^2 < 1423.39 \text{ mm}^2 \]
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

\[ V_{UL} = 208(2180 - 360)/10^3 \]
\[ = 378.56 \text{ kN} \]
\[ K_2 \tau_c = 1 \times 0.96 \]
Nominal shear stress, \( \tau_p = \frac{V_k}{b \cdot d} \)
\[ = \frac{378.56 \times 10^3}{10^3 \times 360} \]
\[ = 0.89 \text{ N/mm}^2 \]
\[ k \tau_c > \tau_p \text{ Hence safe against shear} \]
8. STAAD PRO RESULT

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

**Fig. 7:** Reinforcement details of footing

**Fig. 8:** Bending moment due to dead load

**Fig. 9:** Bending moment due to live load

**Fig. 10:** Bending moment due to load combination

**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
8. RESULT

<table>
<thead>
<tr>
<th>Component</th>
<th>Bending moment</th>
<th>Shear force</th>
<th>Reinforcement Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular slab</td>
<td>$M_b = 889.15$ kN-m</td>
<td>104.2 kN</td>
<td>20 mm dia bars at 120 mm spacing c/c, 10 mm dia bars at 100 mm spacing c/c</td>
</tr>
<tr>
<td>Circular beam</td>
<td>$M = 1110.32$ kN-m</td>
<td>630.45 kN</td>
<td>20 mm dia bars at 125 mm spacing c/c</td>
</tr>
<tr>
<td>Pier cap</td>
<td>-</td>
<td>1260 kN</td>
<td>20 mm dia bars at 300 mm spacing c/c</td>
</tr>
</tbody>
</table>

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.

REFERENCES

[2.] Functional design report Lujiazui Pedestrian in China
[3.] Functional Design Report – Rzeszow Pedestrian crossing in Poland
[4.] Dr. B.C. Punmia – circular slab with hole at the center – Methodology and Design – tenth edition – laxmi publications
[5.] Dr. Sudhir K Jain – Department of Civil Engineering, Indian Institute of Technology, Kanpur – circular beam – methodology and design
[6.] Dr. Alvin Thomas .S – National highway association of India – Pedestrian crossings for Pedestrians – Layout and Dimensions


[10.] IS 456: 2000 – Plain And Reinforced Concrete – Code of Practice


[12.] IRC 21: 2000 – Standard Specifications And Code Of Practice For Road Bridges – Section III – Cement Concrete (Plain And Reinforced)

[13.] NBC – National Building Codes

[14.] SP 16 – Design Aids For Reinforced Concrete to IS 456 – 1978