Intersection Design

Competency 7
Types of Intersection

- Intersections may be classified into two broad groups:
  - **Intersection at grade:** An intersection where all roadways join or cross at the same level
  - **Grade separated intersection:** An intersection layout which permits crossing maneuvers at different levels
At Grade Intersections
Types of At Grade Intersections

- At grade Intersections may be classified into two broad groups:
  - Un channelized intersections
  - Channelized intersections
  - Special type - Rotary Intersection
Un channelized Intersection
Intersection at grade

- **Un channelized intersection:**
  - Intersection area is paved and there is absolutely *no restriction* to vehicles to use any part of intersection area.
  - Hence the un channelized (all-paved) intersections are
    - the lowest class of intersection,
    - easiest in the design but most complex in traffic operations
  - resulting in *maximum conflict area* and more number of accidents, unless controlled by traffic signals or police.
Intersection at grade

- Un channelized intersection:
  - Plain intersection: No provision for additional pavement width for turning movements
  - Flared intersection: Provision for additional pavement width for turning movements
Intersection at grade - Forms of Intersection

- Tee
- Cross
- Staggered
- Skewed
- Skewed cross
- Skewed staggered
- Wye
- Multiple

Fig. 5.33 Forms of Intersections
Fig. 5.34 Unchannelized Intersections
Conflicts at an intersection

Conflicts in a traffic signal
- 4 Through traffic
- 4 Right turn
- 8 Right turn–Through
- 4 Merging
- 4 Diverging
- 8 Pedestrian

Total = 32 Conflicts
Fig. 5.32 Conflict Areas

(a) Area of conflict without channelizing island  (b) Area of conflict with channelizing islands
Fig. 5.35 Channelized Intersections
Traffic Islands
Traffic Islands

- Traffic islands are **raised areas** constructed within the roadway to establish physical channels through which the vehicular traffic may be guided

- **Classification** – based on the function:
  - Divisional islands
  - Channelizing islands
  - Pedestrian loading islands
  - Rotary
Traffic Islands – Divisional

- Intended to separate opposing flow of traffic on a highway with four or more lanes.

- By thus dividing the highway into two one-way roadways, the head on collisions are eliminated and in general other accidents are also reduced.

- The width of the divisional islands should be large if the headlight glare is to be reduced during night driving.

- The kerb should be high enough to prevent vehicles entering into the islands.
Divisional island
Traffic Islands - channelizing

- Used to guide the traffic into proper channel through the intersection area

- Very useful as traffic control devices for intersection at grade, particularly when the area is large

- The size and shape of the channelizing island will very much depend upon the layout and dimensions of the intersection

- Considerable professional experience and skill is required for the successful design of channelizing islands
Channelized island
Traffic Islands – pedestrian loading

- Provided at regular bus stops and similar places for the protection of passengers

- Pedestrian refuge island: A pedestrian island at or near a crosswalk to aid and protect pedestrian crossing the carriage way

- For crossing multilane highways, pedestrian refuge islands after 2 or 3 lanes would be desirable
Pedestrian refuge island
Pedestrian refuge island
Traffic Islands - Rotary

- Large central island of a rotary intersection
- Larger than the central island of channelized intersection
- Crossing maneuver is converted to weaving action by providing weaving length
Rotary Intersection
Channelized Intersection
Intersection at grade

- Channelized intersection:
  - Channelized intersection is achieved by introduction of *islands* into the intersectional area, thus reducing the total conflict area available in the un-channelized intersection.
  - These islands help to channelized turning traffic, to control their *speed* and *angle of approach* and to *decrease the conflict area* at the intersection.
Channelized intersections

Conflicts in a traffic signal:
- 4 Through traffic
- 4 Right turn
- 8 Right turn–Through
- 4 Merging
- 4 Diverging
- 8 Pedestrian

Total = 32 Conflicts
Fig. 5.35 Channelized Intersections
Fig. 5.36 Rotary Intersection
Fig. 5.37 Shapes of Rotary Islands
Intersection at grade

- Channelized intersection:
  - Some examples – figure 3 (on board)
  - Channelization may be partial or complete with divisional and directional islands and medians

- Advantages:
  - Vehicles can be confined to definite paths
  - The channelizing islands provide proper place for installation of signs and other traffic control devices
  - Refuse islands can be provided for pedestrians within the intersection area
Grade separated intersections
Types

- Grade separated Intersections may be classified into following broad groups:
  - Overpass
  - Underpass
  - Interchanges

- This design is the highest form of intersection treatment
- Causes least delay and hazard to the crossing traffic and in general is much superior to intersection at grade from the traffic safety and efficient operation
Rotary Interchange
Diamond type interchange
Partial clover leaf
Clover leaf
Rotary intersection
Overview

- Rotary intersections or roundabouts are special form of at-grade intersections
  - laid out for the movement of traffic in one direction around a central traffic island.

- Essentially all the major conflicts at an intersection namely the collision between through and right-turn movements are converted into milder conflicts namely merging and diverging.

- The vehicles entering the rotary are gently forced to move in a clockwise direction in orderly fashion.

- They then weave out of the rotary to the desired direction.
Rotary Intersection
Advantages

1. Traffic flow is regulated to only one direction of movement, thus eliminating severe conflicts between crossing movements.

2. All the vehicles entering the rotary are gently forced to reduce the speed and continue to move at slower speed. Thus, more of the vehicles need not to be stopped.

3. Because of lower speed of negotiation and elimination of severe conflicts, accidents and their severity are much less in rotaries.

4. Rotaries are *self governing* and do not need practically any control by police or traffic signals.

5. They are ideally suited for moderate traffic, especially with irregular geometry, or intersections with more than three or four approaches.
Disadvantages

1. Even when there is relatively low traffic, the vehicles are forced to reduce their speed.

2. All the vehicles are forced to slow down and negotiate the intersection. Therefore the cumulative delay will be much higher than channelized intersection.

3. Rotaries require large area of relatively at land making them costly at urban areas.

4. The vehicles do not usually stop at a rotary. They accelerate and exit the rotary at relatively high speed. Therefore, they are not suitable when there is high pedestrian movements.
Guidelines for the selection of rotaries

*Because of the above limitation*, rotaries are not suitable for every location.

There are few guidelines that help in deciding the suitability of a rotary:

- Rotaries are suitable when the traffic entering from all the four approaches are relatively equal.
- A total volume of about 3000 veh/hr can be considered as the upper limiting case and a volume of 500 veh/hr is the lower limit.
- A rotary is very beneficial when the proportion of the right-turn traffic is very high; typically if it is more than 30 percent.
- Rotaries are suitable when there are more than four approaches or if there is no separate lanes available for right-turn traffic.
- Rotaries are ideally suited if the intersection geometry is complex.
Traffic operations in a rotary

As noted earlier, the traffic operations at a rotary are three; diverging, merging and weaving. All the other conflicts are converted into these three less severe conflicts.

- **Diverging:** It is a traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.

- **Merging:** Merging is the opposite of diverging. Merging is referred to as the process of joining the traffic coming from different approaches and going to a common destination into a single stream.

- **Weaving:** Weaving is the combined movement of both merging and diverging movements in the same direction.
Design elements

- The design elements include
  - Design speed
  - Radius at entry & exit
  - The central island,
  - Weaving length & width,
  - Entry and exit widths.

- In addition the *capacity of the rotary* can also be determined by using some empirical formula.
Design of a rotary

- exit radius
- entry radius
- entry width
- exit width
- radius of the inscribed circle
- approach width
- weaving length
- weaving width
- circulation width
- splitter island
- radius of the central island
- GIVE WAY line
Design Speed

- All the vehicles are required to reduce their speed at a rotary. Therefore, the design speed of a rotary will be much lower than the roads leading to it.

- Although it is possible to design roundabout without much speed reduction, the geometry may lead to very large size incurring huge cost of construction.

- The normal practice is to keep the design speed as 30 and 40 kmph for urban and rural areas respectively.
Entry, exit and island radius

- The radius at the entry depends on various factors like design speed, super-elevation, and coefficient of friction.
- The entry to the rotary is not straight, but a small curvature is introduced.
- This will force the driver to reduce the speed.
- The speed range of about 20 kmph and 25 kmph is ideal for an urban and rural design respectively.
The exit radius should be higher than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate.

A general practice is to keep the exit radius as 1.5 to 2 times the entry radius.

However, if pedestrian movement is higher at the exit approach, then the exit radius could be set as same as that of the entry radius.
Entry, exit and island radius

- The radius of the central island is governed by the design speed, and the radius of the entry curve.
- The *radius of the central island*, in practice, is given a slightly higher reading so that the movement of the traffic already *in the rotary* will have priority of movement.
- The radius of the central island which is about 1.3 *times that of the entry curve* is adequate for all practical purposes.
Width of the rotary

- The entry width and exit width of the rotary is governed by
  - The traffic entering and leaving the intersection and
  - The width of the approaching road

- The *width of the carriageway at entry and exit* will be lower than the *width of the carriageway at the approaches* to enable reduction of speed.

- IRC suggests that a two lane road of 7 m width should be kept as 7 m for urban roads and 6.5 m for rural roads.

- Further, a three lane road of 10.5 m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads.
Design of a rotary

- exit radius
- entry radius
- entry width
- exit width
- radius of the inscribed circle
- approach width
- weaving length
- weaving width
- splitter island
- radius of the central island
- circulation width
- GIVE WAY line
Width of the rotary

- The width of the weaving section should be higher than the width at entry and exit.
- Normally this will be one lane more than the average entry and exit width.
- Thus weaving width is given as

\[ w_{\text{weaving}} = \left( \frac{e_1 + e_2}{2} \right) + 3.5 \text{m} \]

Where,

- \( e_1 \) - width of the carriageway at the entry and
- \( e_2 \) - carriageway width at exit.
Width of the rotary

- **Weaving length** determines how smoothly the traffic can merge and diverge.

- It is decided based on many factors such as weaving width, proportion of weaving traffic to the non-weaving traffic etc.

- This can be best achieved by making the **ratio of weaving length to the weaving width** very high.

- A ratio of 4 is the minimum value suggested by IRC.

- Very large weaving length is also dangerous, as it may **encourage over-speeding**
Capacity

- The capacity of rotary is determined by the capacity of each weaving section.

- Transportation road research lab (TRL) proposed the following empirical formula to find the capacity of the weaving section.

\[
Q_w = \frac{280w[1 + \frac{e}{w}][1 - \frac{e}{3}]}{1 + \frac{w}{l}}
\]

Where,

- \( e \) - average entry and exit width, i.e, \((e_1+e_2)/2\),
- \( w \) - weaving width,
- \( l \) - length of weaving,
- \( p \) - proportion of weaving traffic to the non-weaving traffic.
Figure shows four types of movements at a weaving section, a and d are the non-weaving traffic and b and c are the weaving traffic. Therefore,

\[ p = \frac{b + c}{a + b + c + d} \]
Capacity formula - validity

1. Weaving width at the rotary is in between 6 and 18 metres.
2. The ratio of average width of the carriage way at entry and exit to the weaving width is in the range of 0.4 to 1.
3. The ratio of weaving width to weaving length of the roundabout is in between 0.12 and 0.4.
4. The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1.
5. The weaving length available at the intersection is in between 18 and 90 m.
The width of approaches for a rotary intersection is 12 m. The entry and exit width at the rotary is 10 m. Table below gives the traffic from the four approaches, traversing the intersection. Find the capacity of the rotary.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Left turn</th>
<th>Straight</th>
<th>Right turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>400</td>
<td>700</td>
<td>300</td>
</tr>
<tr>
<td>South</td>
<td>350</td>
<td>370</td>
<td>420</td>
</tr>
<tr>
<td>East</td>
<td>200</td>
<td>450</td>
<td>550</td>
</tr>
<tr>
<td>West</td>
<td>350</td>
<td>500</td>
<td>520</td>
</tr>
</tbody>
</table>
\[
\begin{align*}
\rho_{ES} &= \frac{450 + 550 + 700 + 520}{200 + 450 + 550 + 700 + 520 + 300} = \frac{2220}{2720} = 0.816 \\
\rho_{WN} &= \frac{370 + 550 + 500 + 520}{350 + 370 + 550 + 500 + 520 + 420} = \frac{1740}{2510} = 0.69 \\
\rho_{NE} &= \frac{420 + 500 + 700 + 300}{520 + 400 + 420 + 500 + 700 + 300} = \frac{1920}{2840} = 0.676 \\
\rho_{SW} &= \frac{450 + 300 + 370 + 420}{550 + 450 + 400 + 370 + 420 + 350} = \frac{1540}{2540} = 0.630
\end{align*}
\]

Thus the proportion of weaving traffic to non-weaving traffic is highest in the East-South direction.

Therefore, the capacity of the rotary will be the capacity of this weaving section. From equation, 
\[
Q_{ES} = \frac{280 \times 13.5 \left[1+\frac{10}{13.5}\right]\left[1-\frac{0.816}{3}\right]}{1+\frac{13.5}{54}} = 380.56 \text{veh/hr.}
\]