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Subject Name: **Highway Engineering**

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Unit III

Low Cost Roads, Drainage of Roads, Traffic Engineering & Transportation Planning:Principles of stabilization, mechanical stabilization, requirements, advantages,Dis-advantages and uses, quality control, macadam roads-types, specifications, construction,Maintenance and causes of failures
Surface and sub-surface drainage, highway materials: properties and testing etc.Channelized and un-channelized intersections, at grade & grade separated intersections,Description, rotary-design elements, advantages and disadvantages, marking, signs,Signals & street lighting. Principles of planning, inventories, trip generation, trip distribution,Model split, traffic assignment, plan preparation.

Introduction:
Low cost roads:- Surfacing is not always necessary to provide an adequate or "good-enough" road. Sometimes the soil already in place along the road line may be sufficiently strong to support small numbers of light vehicles in areas with modest rainfall (up to about 1,000mm/year). The soil must be shaped into a camber to shed rainwater to each side and then consolidated, as a minimum, with hand rammers. The passage of vehicles will also help. Compaction is always necessary to ensure its durability, and it must be maintained with regular reshaping or grading. Such a road is referred to as an 'Engineered Earth Road' or 'Engineered Natural Surface'. Soils with California Bearing Ratio (CBR) strength of about 15 or more can usually be used in this way. Strength may be gauged by using simple low cost apparatus such as the Dynamic Cone Penetrometer (DCP).

However, it is often necessary to stabilize or improve the in-situ soils mechanically, either with other selected soils/aggregates or with cement, bitumen or chemicals, or else construct a stronger pavement on top to support heavier vehicles or higher traffic flows. This will help spread vehicle loads so that they can be carried on the alignment soils without causing deformation.
There is also a range of surfacing or paving options that can be used. Natural gravel surfacing is generally used as the principal low cost solution in many developing countries. This material provides an intermediate surface between basic engineered earth and higher cost, often bituminous, paving. Gravel can be appropriate where suitable material is available and laid to strict surfacing specifications and procedures, gravel haul distances are short (usually less than 10 km), road gradients are less than about 6%, rainfall is low or moderate (less than 2,000mm/year), traffic is relatively low (usually less than about 100 motor vehicles/day), finance and resources are available for periodic regravelling, and dry season dust generation is not severe.
Unfortunately, these requirements are not met in many locations. Naturally occurring lateritic and other suitable gravels tend to be rare with good quality deposits often far from the roads. Transport can become very expensive. Furthermore, gradients can be steep on low volume roads to minimise overall construction costs. When rainfall is intense and concentrated within relatively short periods of the year as is frequently the case, the gravel surface will be quickly washed away. Dry season dust loss leads to the surface disintegrating, to be again washed away during the rainy season, particularly on steep sections. Maintenance of gravel roads is expensive, especially for periodic regravelling, typically required at three to five year intervals, Therefore gravel roads are rarely maintained systematically and many revert eventually to earth standard roads.
There are also environmental problems. Unrestored borrow pits, which fill with water, form loci for erosion and disease while the clouds of dust thrown up by motor vehicles during the dry season are a health and safety hazard, as well as affecting nearby crops and property. In many countries, gravel roads are meeting increasing resistance because of this.

Fortunately, there are alternative surfacing and paving options already tried in various countries that could provide appropriate, economical and sustainable alternatives. Suitability will depend on local circumstances. These alternatives, involving the appropriate use of available materials, may be cheaper in whole-life-cost terms (covering all construction and maintenance costs and vehicle operating cost savings). Many can be carried out by small local enterprises using labour-based methods and light equipment. They could have lower maintenance requirements than gravel, not only in terms of cost but also by reducing the need for heavy equipment to transport and compact, and the resulting damage to haul routes. The many considerations influencing the choice of surface are discussed in this page.

In summary, the window of opportunity for gravel surfaces in developing countries is being squeezed from below by low cost if fragile earth roads, and from above by the increasing awareness of low-cost surfacing alternatives. Gravel surfaces have proved to be relatively costly, taking account of their need for regular replenishment, their low durability, especially in many less-developed countries, and the rapidly declining level of service it provides to users as it deteriorates. As countries, especially in Asia, get richer, dust becomes more unpopular, to the point where communities finance street paving on their own even if the roads leading to their town remain unpaved. Alternative surfaces, many perfected years ago, can now be justified at lower traffic levels than hitherto thought. These include water-bound macadam, hand-laid stone, fired brick paving, simple concrete paving on steep slopes, and low-cost seals. These surfaces are more durable and allow year-round mobility to all types of vehicle.

In developing countries like India the biggest handicap to provide a complete network of road system is the limited finances available to build road by the conventional methods. Therefore there is a need to resort to one of the suitable methods of low cost road construction. The construction cost can be considerably decreased by selecting local materials including local soils for the construction of the lower layers of the pavement such as the sub-base course. If the stability of the local soil is not adequate for supporting wheel loads, the properties are improved by soil stabilization techniques. Thus the principle of soil stabilized road construction involves the effective utilization of local soils & other suitable stabilizining agents.

Highway drainage:

Highway drainage is the process of removing and controlling excess surface and sub-surface water within the right way. This includes interception and diversion of water from the road surface and sub-grade. The installation of suitable surface and sub-surface drainage system is an essential part of highway design and construction.

During rain, part of the rain water flow on surface and part of it percolates through the soil mass as gravitational water until it reaches the ground water below the water table. Removal and diversion of surface water from the roadway and adjoining land is termed as surface drainage, while the removal of excess soil-water from the sub-grade is termed as sub-surface water, some water is retained in the pores of the soil mass and drained off by the normal gravitational method and this water is termed as held water.

Culvert of minimum diameter 75 cm and made of steel or prefabricated RCC is used when the discharge is low.

Various types of bridges are in use; the choice is based on several considerations including the span. RCC and steel bridges are commonly constructed these days.

On less important roads, in order to reduce the construction cost of cross drainage structures,

some time submersible bridges or cause ways are constructed. During the floods the water will flow over the road. The total period interruption to traffic has however to be as low as possible, not exceeding about 15 days in a year.

SUB-SURFACE DRAIN

Change in moisture content of sub-grade are caused by fluctuations in ground water table seepage flow, percolation of rain water and movement of capillary water and even water vapour. In sub-surface drainage of highways, it is attempted to keep the variation of moisture in sub-grade soil to a minimum. However only the gravitational water is drained by the usual drainage systems.

LOWERING OF WATER TABLE

The highest level of water table should be fairly below the level of sub grade, in order that the sub grade and pavements layers are not subjected to excessive moisture. From practical considerations it is suggested that the water table should be kept at least 1.0 to 1.2 meter below the sub grade. In place where water table is high (almost at ground level at times) the best remedy is to take the road formation on embankment of height not less than 1.0 to 1.2 meter. When the formation is to be at or below the general ground level, it would be necessary to lower the water table.

If the soil is relatively permeable, it may be possible to lower the high water table merely construction of longitudinal drainage trenches with drain pipe and filter sand. The depth of the trench would on the required lowering of water table, distance between the drainage trenches and soil type. If the soil is relatively less permeable, the lowering of ground water level may not be adequate at the center of the pavement or in between the two longitudinal drainage trenches. Hence in addition, transverse drainage may have to provide in order to effectively drain off the water and thus lower the water table up to the level of transverse drains.

CONTROL OF SEEPAGE FLOW

When the general ground and impervious strata below are slopping, seepage flow is likely to exist. If the seepage zone is at depth less than 0.6 to 0.9 meter from the sub grade level, longitudinal pipe drain in trench filled with filler material and clay seal may be constructed to intercept the seepage flow.

CONTROL OF CAPILLARY RISE

If the water reaches the sub grade due to capillary rise is likely to be detrimental, it is possible to solve the problem by arresting the capillary rise instead of lowering the water table. The capillary rise may be checked either by capillary cut-off of any one of the following two types:-

1.A layer of granular material of suitable thickness is provided during the construction of embankment, between the sub grade and the highest level of sub surface water table.
The thickness of the granular capillary cut-off layer should be sufficiently higher than the anticipated capillary rise with in the granular layer so that the capillary water cannot rise above the cutoff layer.

2.Another method of providing capillary cut-off is by inserting an impermeable or bituminous layer in the place of granular blanket.

DESIGN OF SUBSURFACE DRAINAGE SYSTEM

The size of spacing of subsurface drainage system would depend on the quantity of water to be drained off, the type of soil and type drains. Mostly this is decided based on experience and other practical considerations. However, proper filter material should be used for back filling the drainage trenches and also for use in all subsurface drainage system.

DESIGN OF FILTER MATERIAL

The filter material used in subsurface drain should be designed to have sufficient permeability offering negligible resistance to the flow. The filter material should also be designed to resist the flowing of the fine foundation soil resulting in problem like piping. Hence the grain size distribution of filter material is decided based on these two criteria of permeability and piping. The procedure for design of filter is briefly discussed below:-

1.On a grain size distribution chart plot the grain size distribution curve for the foundation soil.

2.Find the value of D15 size of foundation material and plot a point of particle size 5D15 of foundation to represent the lower limit of D15 size of filter. This to fulfill the permeability condition given by:- (D15 of filter / D15 of foundation) should be > 5.

3.To fulfill the condition to prevent piping :- (D15 of filter / D85 of foundation) should be less than (<) 5, hence plot a point to represent the upper limits of D15 size of filter given by 5D85 of foundation.

4.Find the size of perforation in the drain pipe or the gap in the open joints pipes and let this be = Dp. Plot a point to represent D85 size of filter given by the size 2Dp.

DRAINAGE OF SLOPES AND EROSION CONTROL

Drainage of slopes and embankment, cutting and hill side are of utmost important to prevent instability of slopes and slides. Soaking of the slope causes stress and reduction in strength. Hence an efficient network of surface drainage system consisting of interception drains and sloping drains to keep the slopes properly drained is very useful for stability. The sloping drains may be provided with lining or pitching or may be filled with gravel. The water from the sloping drains is collected in the catch pits ant diverted across through the culverts at suitable intervals

Mechanics of Soil Stabilization:

The term soil stabilization means the improvement of the stability or bearing power of the soil by the use of controlled compaction, proportioning or the addition of suitable admixture or stabilizers. Soil stabilization deals with physical, physic-chemical & chemical methods to make the stabilized soil serve its purpose as pavement component material. The basic principles in soil stabilization are:

1. **Evaluating the properties of given soil**
2. **Deciding the economical method of stabilization**
3. **Designing the stabilized soil mix**
4. **Compacting the stabilized layers.**

Soil stabilization may result in any one or more of the following changes:

1. Increase in stability, change in properties like density or welling, change in physical characteristics.
2. Change in chemical properties
3. Retaining and desired minimum strength by water proofing.

Soil stabilization Methods:

1. Mechanical soil stabilization
2. Soil cement stabilization
3. Soil lime stabilization
4. Soil bitumen stabilization

Mechanical Soil stabilization:

Correctly proportioned materials (Aggregate & Soil) when adequately compacted to get a mechanically stable layer, the method is called Mechanical Soil Stabilization. The two basic principles in this method are:

1. Proportioning
2. Compaction

If a granular soil containing negligible fines is mixed with a certain proportion of binder soil, it is possible to increase the stability. Similarly the stability of a fine grained soil could be considerably improved by mixing a suitable proportion of granular materials to get a suitable gradation.

Mechanical stabilization has been successfully applied for sub-base & base course constructions. It has also been used as surface course for low cost roads such as village roads when the traffic & rainfall are low.

Factors affecting Mechanical stability:

1. Mechanical strength of aggregates
2. Gradation
3. Properties of soil
4. Presence of salts, mica etc.
5. Compaction

Mix design in Mechanical Stabilization:

The factors to be considered in the design of mix are gradation, density, index properties & stability.

- Gradation: The particle size distribution that gives maximum density is generally aimed at. The theoretical gradation for maximum dry density is generally

$$p = 100(d/D)^n$$

Where, p= percent finer than diameter'd' (mm) in the material

D= diameter of largest particle (mm)

n= gradation index

- Proportioning: When a few materials are available in the near vicinity, it is necessary to mix then in such a proportion which would produce mix with highest density. For example, coarse aggregates, sand & fine soils are available from three deposits, it is first essential to decide the best proportion of these component materials. Two graphical methods are in common use for proportioning are the triangular chart method & Rothfutch's method.
- Density: Standard dry density is obtained in the laboratory compaction test.
- Index properties: Following are recommended values of liquid limit & plasticity index for the material passing 0.425mm sieve

	Base course	Surface course
Liquid limit	25% maximum	35% maximum
Plasticity Index	6% maximum	5 to 10%

- Stability: CBR test is commonly adopted for stability.

Construction procedure:

Materials: The constructions materials are collected from the selected borrow pits & are stacked along the sides of the road in the desired proportion

Equipment: Machinery or manual labor may be used for excavation & haulage. For compaction- rollers of suitable type & weight are used.

Construction steps:

- The sub-grade is prepared
- Materials are mixed to the desired proportions as per design
- The existing moisture content is checked by a rapid method & additional water required is spread & the material is re-mixed
- The wet mix is spread to the desired grade & compacted by the rollers. Rolling is started from edges & with adequate longitudinal over-lap; it is continued up to center.
- Field control test: two field test are necessary:
    1. Determination of moisture content of the mix before compaction
    2. Determination of density during & just after compaction
- Stabilized road is opened to traffic after the compacted layer hardness by drying.

Soil Cement Stabilization:

- Soil cement is an intimate mix of soil, cement & water which is well compacted to form a strong base course.
- In granular soil, the mechanism of stabilization is due to the development of bond between the hydrated cement & the compacted soil particles at the points of contact.

- In fine grained soil, the stabilization is due to reduction in plasticity & formation of matrix enclosing small clay lumps.
- Degree of stabilization depends on nature of soil, proportion of cement, compacting moisture cement & the dry density of the compacted mix.
- Soil cement can be used as a sub-base or base course of all types of pavements.

Factor influencing the properties of soil cement:

- Soil
- Cement
- Pulverizing & Mixing
- Compaction
- Curing
- Additives

Soil: Physical properties of soil like particle size distribution, clay content, specific surface, liquid limit & plasticity index affects the properties of soil cement

Cement: An increase in cement content generally causes increase in strength & durability. Both normal & air entraining cement give almost the same results of stabilization.

Pulverizing & Mixing: Better the pulverization &degree of mixing, higher is the strength. Presence of un-pulverized dry lumps of soil reduces strength & durability of soil-cement.

Compaction: There is optimum moisture content corresponding to maximum value of dry density or strength of a soil-cement mix

Curing: During curing adequate moisture is to be retained. Higher temperature of curing accelerates the rate of gain in strength; the strength also increases with age.

Additives: Various activities to soil-cement which improves the properties, Lime are a useful additive when clayey soil or an organic soil is to be stabilized. Sodium hydroxide, sodium carbonate & calcium chloride are some of the useful chemical additives to soil-cement.

Constructions of soil cement Base Course:

Materials:

The soils to be stabilized, either from site or near-by borrow pits are collected and pulverized. From practical consideration, the following properties are recommended for the soils to be selected:

Passing 4.75mm sieve	>50%
Passing 0.075mm sieve	<50%
Liquid limit	<40%
Plasticity index	<18%

Plants & equipments:

There are two methods of construction:

1. **Mix-in-place method**
2. **Plant mix method**

Construction steps for Mix-in-place method:

- **Preparation of sub-grade or sub-base**
- **Pulverization of soil**
- **Application of cement & dry mixing**
- **Addition or spraying water & remixing**
- **Spreading & grading**
- **Compaction**
- **Curing the soil-cement layer**
- **Joint with old work**
- **Field control tests**

In plant-mix method, large mixing plants are used which can batch the materials (soil, cement & water) mix them & deliver for spreading. Compacting equipments are also needed.

Soil-Lime Stabilization:

- **Soil-lime has been widely used either as a modifier for clayey soil or as a binder.**
- **When clayey soils with high plasticity are treated with lime, the plasticity index is decreased and the soil becomes friable & easy to be pulverized, having less affinity with water.**
- **Lime also imparts some binding action even in granular soils. In fine grained soils there can also be pozzolonic action resulting in added strength.**
- **When clay is treated with lime, the various possible reactions are Base Exchange, coagulation or flocculation, reduction in thickness of water film around clay particles, cementing action & carbonation.**
- **The fine clay particles react with lime & get flocculated or aggregated into larger particle groups which are fairly stable even under subsequent soaking.**
- **The maximum dry density of soil-lime mix is decreased by 2-3 % in terms of untreated soil however this decrease in dry density with the addition of small proportion of lime does not cause reduction in strength.**
- **Soil-lime is quite suitable as sub-base course for high types of pavement & base course for pavements with low traffic.**

Factors affecting soil-lime stabilization:

- **Soil type**

- Lime content
- Types of lime
- Compaction
- Curing
- Additives

Stabilization of soil using Bituminous Materials:

- The basic principles in bituminous stabilization are water proofing & binding.
- By water proofing the inherent strength & other properties of soil could be retained. In case of cohesion-less soils, binding action is also important.
- In granular soil the coarser grains may be individually coated & stuck together by a thin film of bituminous materials.
- But in fine grained soils the bituminous material plugs up the voids between small soil clods, thus water proofing the compacted soil-bitumen.
- Most commonly used materials are cutback bitumen & emulsion.
- After the soil-bitumen is compacted, the layer is cured during which the water & volatiles evaporate & the mix hardens.

Factors affecting the properties of soil-bitumen:

- Soil
- Types of bituminous material
- Amount of bitumen
- Mixing
- Compaction
- Curing
- Additives

Traffic islands:

Traffic islands are raised areas constructed within the roadway to establish physical channels through which the vehicular the vehicular traffic may be guided. Traffic island may be classified based on the function as:

1. Divisional islands
2. Channelizing islands
3. Pedestrian loading islands
4. Rotary

Divisional islands are 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.

Channelizing islands are used to guide the traffic into proper channel through the intersection area. Channelizing islands are very useful as traffic control devices for intersection at grade, particularly when the area is large. The size & shape of the channelizing islands will very much depend upon the layout and dimensions of the intersections. The various uses of properly designed channelizing islands are listed below:

- The area possible conflicts between traffic stream is reduced.
- They established the desired angles of crossing & merging of traffic streams.
- They are useful when the traffic of the flow is to be changed.
- They serve as convenient locations for other traffic control devices.

Pedestrian loading islands are provided at regular bus stops & similar places for the protection of passengers. For crossing multi lane highways, pedestrian refuge island after two or three lanes would be desirable.

Rotary Island is the large central island of a rotary intersection; this island is much larger than the central island of channelized intersection.

Design of intersection: At the intersection there are through, turning & crossing traffic and these traffic movements may be handled in different ways depending on the type of intersection and its design.

- Intersection at grade: These include all roads which meet at more or less the same level. The traffic maneuvers like merging, diverging & crossing are involved in the intersections at the grade.
- Grade separated intersection: The intersecting roads are separated by difference in level, thus eliminating the crossing maneuvers.

Un-channelized intersections:

- The intersection area is paved & there is absolutely no restriction to vehicles to use any part of intersection area.
- Hence the un-channelized 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.
- When no additional pavement width for turning movement Is provided, it is called plain intersection.
- But when the pavement is widened at the intersection area, by a traffic lane or more, it is known as flared intersection.

Channelized intersections:

- Channelized intersection is achieved by introducing islands into the intersectional area, thus reducing the total conflict area available in the un-channelized intersection.

- The radius of the entrance & exit curves and the area are suitably designed to accommodate the channelizing islands of proper size & shape.
- These islands help to channelized turning traffic, to control their speed & angle of approach and to decrease the conflict area at the intersection.

The advantages of the channelized intersections are:

- By canalization vehicles can be confined to definite paths.
- Angle of merging streams can be forced to be at flat angles so as to cause minimum disruption.
- Angle between intersecting streams of traffic may be kept as desired in a favorable way.
- Speed control can be established over vehicles entering the intersections.
- Point of conflicts can be separated.

Rotary intersection: Rotary:-

Rotary intersections or round abouts 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. The benefits, design principles, capacity of rotary etc.

Advantages and disadvantages of rotary

The key advantages of a rotary intersection are listed below:

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, none of the vehicles need to be stopped,unlike in a signalized intersection.

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.

Although rotaries offer some distinct advantages, there are few specific limitations for rotaries which are listed below.

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

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

3. Rotaries require large area of relatively flat 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. They are listed below. 1. Rotaries are suitable when the traffic entering from all the four approaches are relatively equal. 2. A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is the lower limit. 3. A rotary is very beneficial when the proportion of the right-turn traffic is very high; typically if it is more than 30 percent. 4. 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.

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

2. 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.

3. 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 and the central island, weaving length and width, entry and exit widths. In addition the capacity of the rotary can also be determined by using some empirical formula.

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 entry radius of about 20 and 25 metres 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. 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 radius so that the movement of the traffic already in the rotary will have priority. The radius of the central island which is about 1.3 times that of the entry curve is adequate for all practical purposes.

Weaving operation in a rotary

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. 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

$$\text{weaving} = \frac{e_1 + e_2}{2} + 3.5m$$

where e_1 is the width of the carriageway at the entry and e_2 is the carriageway width at exit.

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. $Q_w = \frac{280w\left[1 + \frac{e}{w}\right]\left[1 - \frac{p}{3}\right]}{1 + \frac{w}{l}}$

where e is the average entry and exit width, i.e, $\frac{(e_1+e_2)}{2}$, w is the weaving width, l is the length of weaving, and p is the proportion of weaving traffic to the non-weaving traffic. types of movements at a weaving section, a and d are the non-weaving traffic and b and c are the weaving traffic. Therefore, $p = \frac{b + c}{a + b + c + d}$

This capacity formula is valid only if the following conditions are satisfied.

1. Weaving width at the rotary is in between 6 and 18 metres.
2. Traffic approaching the rotary 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.
3. The ratio of weaving width to weaving length of the roundabout is in between 0.12 and 0.4. 4.
4. The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1. 5.

5. The weaving length available at the intersection is in between 18 and 90 m.

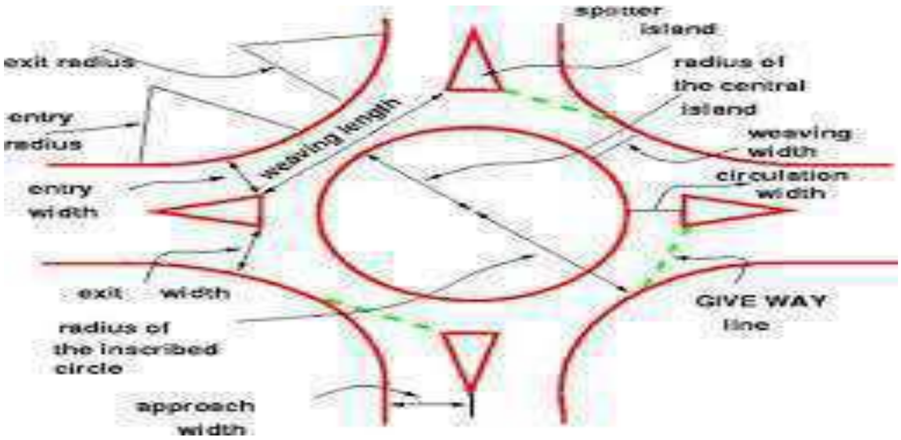

Fig 1 Rotary intersection

Highway lightening:

The rate of highway accidents & fatalities that occur during night driving is several times higher in terms of vehicle-kilometer, than that during day driving. One of the various causes of increased accident rate during night may be attributed to poor night visibility. Highway lighting is particularly more important at intersections, bridge site, level crossings & in places where is restriction of traffic to movements. On urban roads where the density of population is also high, road lighting has other advantages like feeling of security & protection.

During night driving the manner in which the objects are visible varies with both the absolute level of brightness and the relative brightness of the road surface and the object. A light colored, rough textured pavement surface can reflect back is considered more desirable. When the pavement surface is very dark like black top surface, the objects which are relatively brighter in color are seen by this process.

Thus the various factors that influence night visibility are:

- Amount & distribution of light flux from the lamps
- Size of object
- Brightness of object
- Brightness of background
- Reflecting characteristics of the pavement surface
- Glare on the eyes of the driver
- Time available to see an object

Design factors of Highway lighting:

- Lamps
- Luminaries distribution of light
- Spacing of lighting units

- Height & over-hang of mounting
- Lateral placement
- Lighting layouts

Lamps: The choice of the lamp, its type, size & color depends upon several considerations in addition to distribution of light flux on the pavement surface. The various types of lamps in use for highway lighting are filament, fluorescent & sodium or mercury vapor lamps. The cheapest among these is the filament lamp.

Luminaire distribution of light: To have the best utility or source of light, it is necessary to have proper distribution of light. The distribution should be downward so that high percentage of lamp light is utilized for illuminating the pavement and adjacent area. The distribution from the Luminaire should cover the pavement between the kerbs & provide adequate lighting on adjacent area i.e 3m to 5m beyond the pavement edge.

Spacing of lighting units: It is often influenced by the electrical distribution poles, property lines, road layout & type of side features & their illumination. Large lamps with high mountings & wide spacing's should be preferred from economy point of view.

Height & over-hang of mounting: The distribution of light, shadow & the glare effect from street lamps depends also on the mounting height. The glare on eyes from the mounted lights increases with the power of the lamp directed towards the eye & decreases with increase in height of mounting. Usual mounting heights range from 6m to 10m.

Traffic & Transportation planning:

Traffic planning:

The problem of traffic accidents & congestion in urban roads is being viewed with grave concern in the recent years. The main causes for this problem are improper planning of road network & other road way facilities and poor traffic planning. Hence traffic functions now occupy a good position in corporation & municipalities. In municipal organizations a fully fledged traffic engineering unit can be entrusted to look after public safety. Such a traffic engineering unit may have several divisions such as:

- Field studies
- Accident analysis
- Traffic control devices
- Design & planning
- Special investigations
- Economic analysis & decision theory in engineering design and
- Administration

Urban transportation planning process:

The transportation planning process is developed in a series of stages:

- **Inventories**
- **Trip generation**
- **Trip distribution**
- **Model split**
- **Traffic assignment**
- **Plan preparation and evaluation**

Inventories: information related to land use, economic activity, population; travel characteristics and transportation facilities are collected through a series of surveys. For this purpose the metro Politian area under study is sub-divided into number of smaller zones:

- **Zones should be homogeneous in land use**
- **Zones should be homogeneous traffic generating characteristics**
- **Zones should conform to enumeration districts, natural and physical barriers.**
- **Zones should not be large enough to produce errors resulting from the assumption that all activities occur at zonal centroid.**
- **Zones should preferably have geometrical shape for easy determination of centroid.**

Trip Generation: This is the first stage of the travel demand forecasting process. Trip generation concerns with the estimation of number of trips produced In or attracted to a given zone. The trip is defined as "One-way movement having single purpose & mode of travel between a point of origin & a point of destination". Two popular methods of trip generation estimation are:

- **Multiple regression analysis**
- **Category analysis**

Trip distribution: It is the stage where the trips generated and attracted from ach zone are distributed to any other zone. The most important method for this procedure is the gravity model. This method is based on the principle that the trips between any two zones say I & j are directly proportional to the number of trips generated in the zone I, the number of trips attracted to zone j and are inversely proportional to some function of distance or separation between the zones. The model is as follows:

$$T_{ij} = G_i \; A_j F_{ij} / \sum A_i F_{ij}$$

Here,

T_{ij}= number of trips from zone I to j

G_i = trips generated in zone i

A_j = trips attracted to zone j

F_{ij} = empirically derived 'friction factor' calculated on area wise basis

n = number of zones in the urban area

Grade intersection:-

Grade separation is a method of aligning a junction of two or more surface transport axes at different heights (grades) so that they will not disrupt the traffic flow on other transit routes when they cross each other. The composition of such transport axes does not have to be uniform; it can consist of a mixture of roads, footpaths, railways, canals, or airport runways. Bridges (or overpasses or flyovers), tunnels (or underpasses), or a combination of both can be built at a junction to achieve the needed grade separation.

Advantages

Roads with grade separation generally allow traffic to move freely, with fewer interruptions, and at higher overall speeds; this is why speed limits are typically higher for grade-separated roads. In addition, less trouble between traffic movements reduces the risk of accidents.

Disadvantages

- Grade-separated road junctions are typically space-intensive, complicated, and costly, due to the need for large physical structures such as tunnels, ramps, and bridges.
- Their height can be obtrusive, and this combined with the large traffic volumes that grade-separated roads attract, tend to make them unpopular to nearby landowners and residents. For these reasons, proposals for new grade-separated roads can receive significant public opposition.

Rail-over-rail grade separations take up less space than road grade separations: because shoulders are not needed, there are generally fewer branches and side road connections to accommodate (because a partial grade separation will accomplish more improvement than for a road), and because at-grade railway connections often take up significant space on their own. However, they require significant engineering effort, and are very expensive and time-consuming to construct.

Grade-separated pedestrian and cycling routes often require modest space since they do not typically intersect with the facility (such as a highway) that they cross.

Grade-separation can create accessibility problems for people with disabilities due to the vertical gradient required to pass or to reach rail platforms.

Grade-separated roads that permit for higher speed limits can actually reduce safety due to 'weaving' (see below) as well as a perceived sense of safety.

The term is most widely applied to describe a road junction in which the direct flow of traffic on one or more of the roads is not disrupted. Instead of a direct connection, traffic must use on and off ramps or slip roads to access the other roads at the junction. The road which carries on through the junction can also be referred to as grade separated.

Typically, large freeways, highways, motorways, or dual carriageways are chosen to be grade separated, through their entire length or for part of it. Grade separation drastically increases the capacity of a road compared to an identical road with at-grade junctions. For instance, it is extremely uncommon to find an at-grade junction on a British motorway; it is all but impossible on a U.S. Interstate Highway, though a few do exist.

If traffic can traverse the junction from any direction without being forced to come to a halt, then the junction is described as fully grade separated or free-flowing.

1. Fully separated
2. Stack interchange (two-level, three-level, or four-level stack, depending on how many levels cross at the central point)
3. Cloverleaf interchange
4. Partially separated
5. Diamond interchange
6. Partial cloverleaf interchange
7. Single-point urban interchange
8. Roundabout interchange
9. Compact grade-separation,

Whereby the two roads are linked by a compact "connector road", with major-minor priority junctions at each of its ends; usually a variant of the cloverleaf type interchange, but only involving two quadrants rather than four

