USN | | | | | | | | | |

Internal Assessment Test 1 – September 2018

Sub:	Highway Geometric design				Sub Code:	10CV755	Branch :	CIVIL
Date:	10/9/2018	Duration:	90 mins	Max Marks: 50	Sem / Sec:	Exit Scheme		OBE

Answer any **FIVE FULL** Questions OUT OF **SIX** — MARKS | CO | RBT

1 Briefly discuss the various design factors to be considered for the geometric design of highways. [10] CO1 L2

The following are the design factors to be considered for geometric design:

1.Topography

A terrain is characterized by its cross slope. Cross slope is the slope of the land perpendicular center line of the highway. It is easier to construct roads with required standards for a plain terrain. However, for a given design speed, the construction cost differs with the terrain. Therefore, geometric design standards are different for different terrain to keep the cost of construction and time of construction under control. This is characterized by sharper curves and steeper gradients. The design speed changes with terrain.

Table 1:1 – Terrain Classification

No.	Terrain Classification	Percent cross slope
1	Plain	0 to 10
2	Rolling	10 to 25
3	Mountainous	25 to 60
4	Steep	>60

Curves and gradient increases, design speed reduces.

2.Traffic

Traffic data like traffic volume, vehicular and user characteristics, traffic composition and future traffic estimates affects the geometric features like width, alignment, grades etc.

- **Traffic volume**

Design hourly volume – Hourly volume is the number of vehicles that pass across a transverse line of the road in an hour. AADT is the average daily traffic volume for a year (annual volume of traffic divided by 365 days). AADT is not the design volume for geometric design as it doesn't include the variations of traffic between months, weeks, days or hours. Hence for geometric design the traffic volume for design is the 30^{th} highest hourly volume. It is the hourly volume that is exceeded 29 times in a year. The highest peak hourly volume in the year will be too high and thus costly. Hence using 30^{th} highest hourly volume reduces cost as well causes congestion only 29 hours in a year which is reasonable. It is found out that 30^{th} highest hourly volume is 8 – 10 % of AADT in Indian roads.

- **Traffic capacity**

Traffic capacity is the maximum traffic flow that can be accommodated in a highway. The traffic volume to capacity ratio determines the level of service of the road.

- **Traffic composition**

The traffic is heterogeneous. It consists of cars, trucks, buses and slow animal drawn vehicles. The vehicle characteristics are different hence it is converted to an equivalent number of a “standard vehicle” known as Passenger car Units.

- **Future Traffic**

The geometric design should include the current traffic as well as 20 years future estimate of traffic.

- **Road User characteristics**

The physical (vision and hearing), mental, psychological and environmental factors affecting road user characteristics also affects the geometric design.

- **Vehicle dimensions**

Vehicular dimensions like length, width and height affects the geometric design. The width of the vehicle affects the width of lanes, shoulders and parking facility. The length of the vehicle affects the extra width at horizontal curves, minimum turning radius (depends on length of wheel base), safe overtaking distance, capacity of road etc. The height of the vehicle determines the clearances to be provided under structures like bridges.

3.Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of a highway when conditions are so favourable. It is the speed only 2 % vehicles exceed on the highway (98^{th} percentile speed).

Design speed is the most important factor affecting geometric design. It depends on the importance of road and the type of terrain. Design speed affects the pavement surface characteristics, cross-section elements (width and clearance requirements), sight distance, horizontal alignment elements (radius of curve, super elevation, transition curve length) and the vertical alignment elements (gradient, length of valley curve and summit curves).

Terrain classification	Cross slope (%)
Plain	0-10
Rolling	10-25
Mountainous	25-60
Steep	> 60

Type	Plain	Rolling	Hilly	Steep
NS&SH	100-80	80-65	50-40	40-30
MDR	80-65	65-50	40-30	30-20
ODR	65-50	50-40	30-25	25-20
VR	50-40	40-35	25-20	25-20

4.Environmental factors:

The environmental factors such as aesthetics, landscaping, air pollution, noise pollution and other local conditions should be given due consideration in the design of geometrics.

2 Briefly explain the various factors which affect the road user characteristics and their effect on traffic perfomance. [10] CO1 L2

The road user characteristics can be classified in to:

i. Physical characteristics – Permanent characteristics include vision, hearing, strength and general reaction to traffic situations. Vision includes the following aspects like sharpness of vision (how well we can see), peripheral vision (side vision), eye movement (includes the voluntary or involuntary movement of the eyes, helping in acquiring, fixating and tracking visual stimuli), depth judgement (the real distances and the distances perceived by eyes will be different), glare vision and the time required for glare recovery is important at night.
   - Sharpness of vision - minimum standards are fixed laid by licensing authorities.
   - Peripheral vision – in the horizontal plane we can see clearly within a 3^0 cone. Satisfactorily we can see up to within 20^0 cone. In the vertical field vision is satisfactory within two thirds of that in the horizontal plane. These factors are taken in to design aspects of a roadway.
   - Eye movements – road users have to shift their eyes for clear vision.
   - Depth judgment – it is important for a driver in judging distance and speed of vehicles ahead.
   - Glare vison – the adoptability to changes of light (changes from darkness to light, bright light to darkness comes under glare vision.

   Hearing is important for drivers while its more useful for the pedestrians. Strength is an important factor in the parking manoeuvres of heavy vehicles. Temporary characteristics include fatigue, alcohol, drugs and illness. \
ii. Mental factors – Knowledge, skill, experience and literacy can affect the road user characteristics. Knowledge of traffic rules, vehicle characteristics, traffic behavior, and psychology of drivers is useful for traffic operations. Reaction to certain traffic situations becomes spontaneous with experience.
iii. Psychological factors – emotional factors like fear, attentiveness, anger, impatience, maturity, general attitude towards traffic and regulations affect reaction of road users to a great extent. Distractions by non-traffic events and worries reduce attentiveness to traffic situations. Impatience can lead to dangerous activities.
iv. Environmental factors – this include the traffic stream characteristics, roadside features, atmospheric conditions and the locality. The traffic stream will be mixed. The more the percentage of slow moving traffic greater is the need for overtaking for fast moving traffic. The road user behavior depends on the adaptability to a traffic stream which depends on the driver's physical, mental and psychological factors as well as his motivation. The way a user drives through a traffic stream depends on the purpose for entering the traffic like social, recreational, business or an emergency dash. Sometime locality like a shopping Centre can distract a driver. The other factors of importance are weather, visibility and other atmospheric conditions.

3 Write short notes on [10] CO2 L1

(a)Traffic capacity

Traffic capacity

Traffic capacity of a roadway is the maximum allowable traffic volume per unit time (traffic flow). Expressed as vehicles (PCU) per hour per lane. Traffic volume change with variations in traffic but traffic capacity is a maximum capability of traffic flow. There are different types of traffic capacity:

- Basic capacity – It is the traffic capacity under nearly ideal roadway and traffic conditons. It is the theoretical maximum capacity.
- Possible capacity - It is the traffic capacity under existing roadway and traffic conditons. Possible capacity can take values between 0 (full congested) and basic capacity (ideal condition).
- Practical capacity – It is the traffic capacity for which a roadway is designed (**Design capacity**). This capacity avoids unreasonable delay and restriction to freedom of driver to manoeuvre under prevailing conditions.

Determination of theroretical maximum capacity

$$q_c = \frac{1000\,V}{S}$$

Where,

q_c is theroretical maximum capacity

V is the design speed in kmph

S is the average center to center spacing of vehicles in the stream also known as **space headway**.

S = vt + L

Where,

v is the velocity in m/s

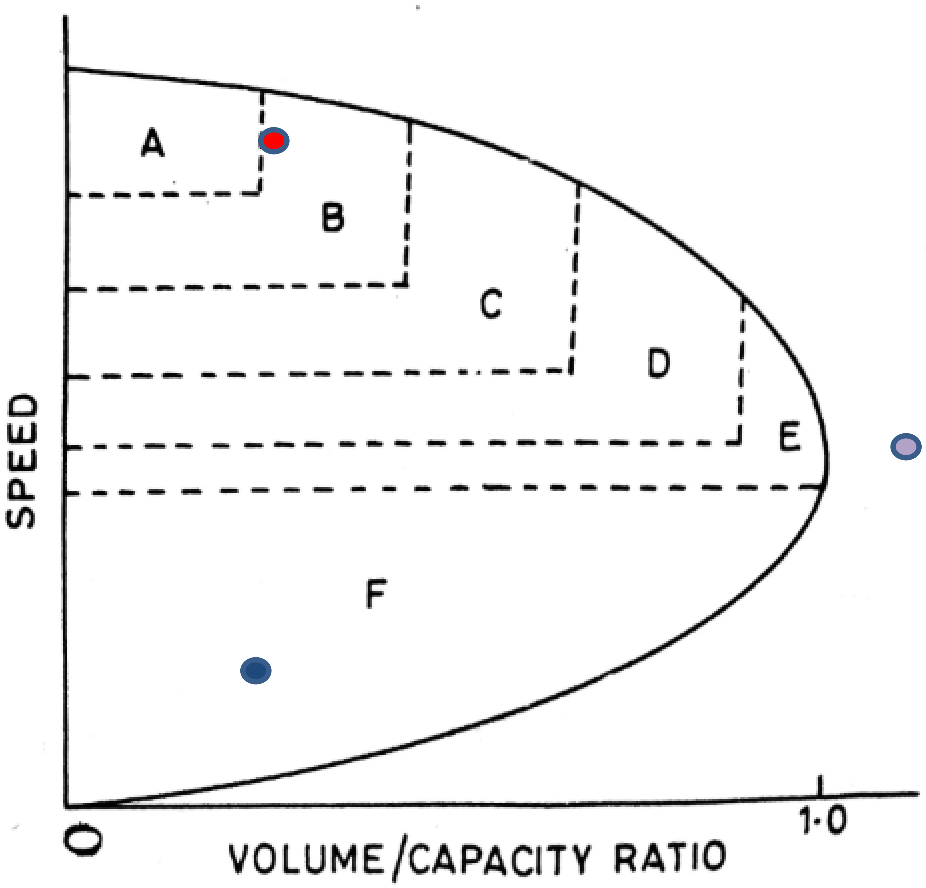
L is the length of the vehicle

t is the reaction time in seconds

Level of service of roads

The design capacity is decided based on the level of service which is a pre-requisite for geometric design. The level of service is the level of facility that can be derived from a road. It depends on two factors:

- The operating speed
- The ratio of traffic volume to traffic capacity



Any operating speed, volume/capacity ratio combination which makes the point comes in A region comes under Level of service A (red dot). These roads have high speed vehicles but the number of vehicles passing the transverse section per unit time is less (low traffic volume). This indicates free flow, no delay, no restriction to speed other than speed limits. The same low traffic volume can be encountered when operating speed is low indicating congestion. In that case the level of service of the road is E (blue dot). The volume capacity ratio reaches 1 only at optimum speed (yellow dot). As the operating speed decreases below the optimum speed the traffic volume ratio drops indicating congestion. Above the optimum speed high speed indicates free flow and lower speeds indicate the vehicles travelling at theoretical capacity. A high level of service give the driver the choice of speed without restrictions. A low level of service takes away the freedom of the driver to select speed, maneuver and overtake with long periods of stoppages.

Factors affecting practical capacity or theoretical capacity:

- Lane width – capacity is inversely proportional to lane width
- Lateral clearance – a minimum clearance of 1.85 m from the pavement edge to the obstruction (retaining walls) for the capacity to not get affected.
- Width of shoulders – insufficient shoulder width reduces traffic capacity.
- Commercial vehicles – heavy vehicles occupy greater space and travel with lesser speed.
- Alignment – if the alignment are such that the sight distances are restricted traffic capacity reduces.
- Road geometrics – sharp horizontal curves and steep gradients necessitate speed changes thus reduces the traffic capacity.

- Presence of intersections at grade – intersections resist traffic flow.

(b)Design vehicle

Design vehicle is a selected motor vehicle such that its weight, dimensions and operating characteristics are used to decide the highway geometric design as well as pavement design to accommodate vehicles of a designated type. (for example a road designed for passenger car may not be able to accommodate a larger vehicle). Design vehicle is defined as the vehicle that must regularly be accommodated on a roadway without encroachment into other travel lanes.

The dimensions and operating characteristics of a vehicle profoundly influence the geometric aspects of the road such as:

- Radii of curves
- Width of pavements
- Clearances
- Parking geometrics

The weight of axles and the weight of vehicles affect the structural design of pavements as well as how the vehicle operates on a gradient.

Because of its crucial importance, the standardization of the dimensions and weights of design vehicles is the first step in formulating the geometric design. India follows IRC while US follows AASHTO.

AASHTO and IRC has developed several profiles for commonly-used design vehicles.

AASHTO RECOMMENDS FOLLOWING DESIGN VEHICLES
Passenger Car
Single Unit Truck
Single Unit Bus
Semi Trailer combination, intermediate
Semi Trailer combination, large
Semi Trailer combination, combination

IRC RECOMMENDS FOLLOWING DESIGN VEHICLES
Passenger Car
Single Unit Truck
Semi Trailer
Truck trailer Trailer combination

Larger design vehicles require larger roadway dimensions, particularly at intersections. There are a number of tradeoffs inherent in design vehicle selection. The design vehicle selected for a given roadway should represent the largest vehicle that regularly or frequently, not occasionally, uses it. Selecting too large a design vehicle for a roadway or roadway segment will result in wider lanes and intersections, jeopardizing safety for other modes and leaving less space for pedestrian, bicycle and transit infrastructure.

Selecting too small a design vehicle can make turning maneuvers difficult or impossible for larger vehicles, potentially causing congestion and/or safety issues. Balancing these tradeoffs is an essential component of creating a great street which adequately serves regular users and is appropriate for the place type

Table 6.5. Standards of dimensions for design vehicles by various authorities (in metres)

Authority/ Country	Maximum Width	Maximum Height	Maximum length			
			Passenger car	Single unit Truck	Semi Trailer	Truck Trailer
AASHTO (USA)	2.59	4.12	5.8	9.14	16.8	8.91
U.K.	2.5	4.57 (bus)	5.5	11.0	18.0	13.0
IRC (1983)	2.5	3.8—4.2 (Truck) 4.75 (Double Decker Bus)	—	11.0	16.0	18.0

The turning radii for the various AASHTO design vehicles are given in Tal

Table 6.6. Turning radii of AASHTO design vehicle (in metres)

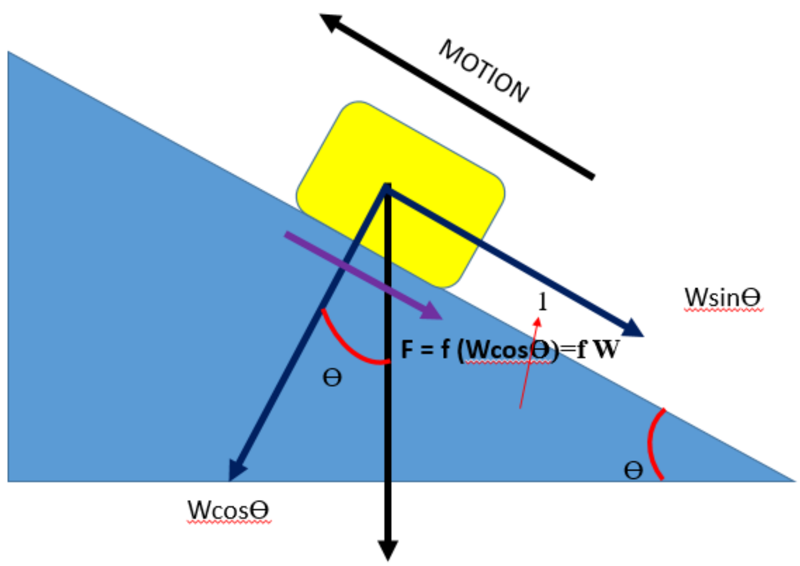
Table 6.6. Turning radii of AASHTO design vehicle (in metres)

Design Vehicle Type	Passenger Car (P)	Single Unit Truck (SU)	Semitrailer (large) (WB—50)	Sem
Minimum Turning Radius (m)	7.32	12.8	13.72	
Minimum Inside Radius (m)	4.65	8.61	6.00	

The turning radii for some of the vehicles in common use are given in Fig.

6.3.4.4. Axle loads and

4 (a) Derive the expression for SSD for an ascending gradient of n% with diagrams. [05] CO1 L3



When there is an ascending gradient of say, + n% the component of gravity ad the braking action and hence the braking distance is decreased. The compone gravity acting parallel to the surface which adds to the braking force is equ $W \sin \alpha \approx W \tan \alpha = (Wn/100)$.

Equating kinetic energy and work done,

$$\left(fW + \frac{Wn}{100}\right)l = \frac{1}{2}\frac{Wv^2}{g}$$

$$l = \frac{v^2}{2g\left(f + \frac{n}{100}\right)}$$

(b) The design speed of a road is 65 kmph, the friction coefficient is 0.36 and reaction time of the driver is 2.5 s. Calculate the values of [05] CO1 L3

(a) Headlight sight distance

(b) Intermediate sight distance required for the road.

$$\text{Stopping sight distance, SSD} = 0.278\,Vt + \frac{V^2}{254f}$$

$$= 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.36} = 91.4 \text{ m}$$

(i) Head light sight distance = SSD = 91.4 m

(ii) Intermediate sight distance, ISD = 2 SSD = 2 × 91.4 = 182.8 m, say 1

5 Two vehicles A and B are moving in the same direction with speeds of 100 kmph and 80kmph with 70 % and 50 % brake efficiency respectively. An object is seen by both the drivers on the road approximately at a distance of 210 m. Find: [10] CO1 L3

(a) Which vehicle will meet with an accident

(b) If the accident is to be avoided what is the braking efficiency required?

$$\text{SSD of vehicle A} = vt + \frac{v^2}{2gf} \times \frac{1}{\eta}$$

$$= \left(100 \times \frac{5}{18} \times 2.5\right) + \frac{(100 \times 5/18)^2}{2 \times 9.81 \times 0.35} \times \frac{1}{0.}$$

$=$

> 210 m

Hence vehicle A will meet with an accide

Braking efficiency of vehicle A to prevent the accident is η'

$$100\times\frac{5}{18} + \frac{(100\times 5/18)^2}{2\times 9.81\times 0.35}\times\frac{1}{\eta'} = 210$$

$$\Rightarrow \eta' =$$

SSD of vehicle B $= vt + \frac{v^2}{2gf}\times\frac{1}{\eta}$

$$= \left(80\times\frac{5}{18}\times 2.5\right) + \frac{(80\times 5/18)^2}{2\times 9.81\times 0.35}\times\frac{1}{0.5}$$

$=$

< 210

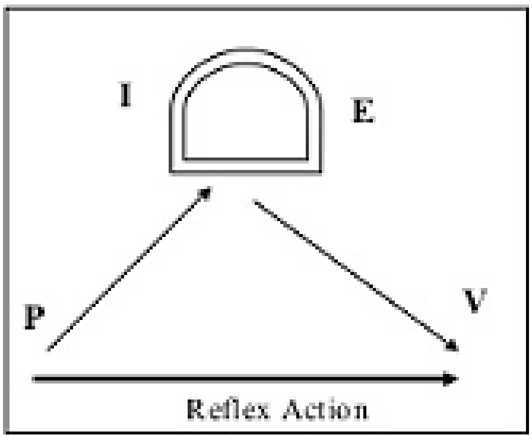
Safe.

6 What is stopping sight distance and what are the factors affecting stopping sight distance? [10] CO2 L2

- Reaction time - The reaction time is the time taken from the instant the object is visible to the driver to the instant the brakes are applied. During this time the vehicle travels a distance in design speed or original speed. The stopping sight distance increases if reaction time increases.

The total reaction time is split into four parts according to PIEV theory:

- Perception time – the time taken to recognize or realize the stimulus.
- Intellection time – the time required for an interpretation/identification of the stimulus.
- Emotion time – the time elapsed in the response to the stimulus which can be anger, fear or superstition.
- Volition time – the time for the final physical action resulting from the decision.



Let us consider a driver approaching a stop sign then perception is the process where the driver sees the sign. Intellection is the process where the driver recognizes the sign. Emotion is the process where he decides to stop and volition is the period where he finally puts his foot on the brake.
The total reaction time of a driver can vary from 0.5 s to 4 s. some drivers may perform the right action within no time (reflex action) without thinking.

- The speed of the vehicle - Stopping sight distance is the sum of lag distance and braking distance. Lag distance is the distance travelled during the total reaction time which depends on the initial speed. The braking distance which is the distance travelled during braking till halt also depends on the initial speed. More the initial speed more is the stopping distance.

- Braking efficiency - A 100% efficient brake will stop the vehicle at the moment the brakes are applied but practically it is not possible. The efficiency of a brake depends upon the braking system, age, maintenance, vehicle characteristics, etc. Thus more sight distance is required when the brake efficiency is less. Practically we assume that the brake efficiency is about 50%. A 100% brake efficiency will lock the wheel completely on the application of brakes which will cause skidding. Hence the Braking force shouldn’t exceed the frictional force

- Frictional resistance between the tire and the road - It depends on the condition of road as well as the tire. The braking distance increases with the decrease in friction resistance. IRC has specified a friction coefficient of 0.35 to 0.4 depending upon the speed used in braking distance calculation.

- The gradient of the road – Stopping sight distance is more on descending gradient than on ascending gradient. This is because weight component acts like an opposing force to motion on ascending gradients and the reverse on a descending gradient.