CV0425-Metro Systems and Engineering

Unit-1: Civil Engineering Aspects

Options for Public Transport System

The following systems are mainly available for Urban Mass Transit:

i) High Capacity Metro System: Metro system is a grade separated dedicated system for high peak hour traffic densities exceeding 40,000 PHPDT. It is characterized by short distances of stations spaced at 1 km, high acceleration and declaration and average speeds of 30-35 kmph.

ii) Light Capacity Metro System: This is a dedicated metro rail system for moderate peak hour traffic densities exceeding 8000 PHPDT.

iii) Light Rail Transit: Modern trams-Street Cars running on Rails at grade or elevated with sharp curves of 24m radius. These are extremely popular and operating in large number of European countries. Generally the stations are spaced at 500m to 1 km and have high acceleration and deceleration characteristics. In most of the countries, they are operating at-grade with prioritized signaling at road inter-section.

iv) Sky Train: This is an experimental rail based system under development by
Konkan Railway.

v) Other Rail Based Systems: A number of options are available but have not been introduced in India.

Some of these are very briefly mentioned below:

(a) Maglev

This is an advanced Rail based transit system in which Magnetic Levitation is used to raise the vehicles above the rail surface. Rail wheel interaction is thus avoided and very high speeds are attainable. Maglev Levitation can either be due to attractive force or due to repulsive forces.

(b) Linear Induction Motor (LIM) Train

This is also an advanced Rail based transit system in which propulsion is through a Linear Induction Motor whose stator is spread along the track. The rotor is a magnetic material provided in the under frame of train. In the technology the tractive force is not transmitted through rail-wheel interaction, and so there is no limitation on account of adhesion. This technology is most appropriate for turnouts, as the height of the tunnel can be reduced to lower height of cars.

(c) Monorail

Monorail trains operate on grade separated dedicated corridors with sharp curves of up to 50m radius. This is a rubber tyred based rolling stock, electrically propelled on concrete beams known as guide-ways. The system is extremely suitable in narrow corridors as it requires minimum right of way on existing roads and permits light and air and is more environmental friendly. This is prevalent in several countries for traffic densities of over 20,000 PHPDT.

(d) Bus Rapid Transit System

This system involves operation of buses on a dedicated corridor (except of traffic integration) at a high frequency to achieve PHPDT. For providing a very high-transport capacity say 20,000 PHPDT, about 200 buses shall be required per hour *i.e.*, at headway of 20 seconds. Such a high PHPDT can be achieved by providing two lanes of traffic in each direction and elimination of traffic intersection on the route.

(e) Automated Guide way Transit System

The term is used for systems other than conventional rail based system on grade separated guide ways. The system can be rail based or rubber tire based but fully automated guided systems with driver less operation.

Capacity of Various Modes (as per the recommendations of Working Group on Urban Transport for 12th Five Year Plan)

In their report **on Urban Transport for 12th Five Year Plan**, the Working Group has set the guidelines for the choice of different modes are as follows:

Table 0.2 - Guidelines for the Choice of Different Modes

SYSTEM	PHPDT IN 2021	POPULATION IN 2011	AVG. TRIP LENGTH
Metro Rail #	>=15000 for at least 5km continuous length	More than 20 Lakhs	More than 7 Km
LRT primarily at grade	=<10,000	More than 10 Lakhs	More than 7 Km

Monorail @@	=<10,000	More than 20 Lakhs	About 5-6 Km
Bus Rapid Transit System	>=4,000 and upto 20000	More than 10 Lakhs	>5 Km
Organized City Bus Service as per urban bus specifications	—	>1 lac, >50,000 in case of hilly towns	>2 to 3 Km

 # for having Metro Rail, the city should have a ridership of at least 1 million on organized public transport (any mode)
***@@ Monorail is desirable only as a feeder system or where the narrow roads are flanked on either side by high rise buildings. In monorail while the cost of construction, operation and maintenance is almost the same as elevated metro rail, the carrying capacity is much lesser*.**

SELECTION OF MODE

Selection of a particular mode for any pre-determined traffic corridor depends mainly on demand level of a corridor Right of Way (ROW) on the road and the capacity of the mode. The demand forecast is estimated considering the traffic growth for about 30 years. Other considerations in mode choice are, location of building lines, possibility of increasing ROW. Cost of some mode may vary depending up on the location in view of engineering constraints. Therefore final choice of mode to be adopted for a particular corridor is based on techno economic considerations. As regards the location of a particular mode like at-grade, elevated and underground depends up on the ROW. If ROW is 20 M or more, elevated alignment is preferred over underground as the cost of underground alignment is 2- 2½ times of elevated alignment. Hence, keeping in view the above points, it is recommended to adopt a stable, tested and reliable Metro technology i.e. **Light Capacity Metro System** having capacity to cater PHPDT from 15000 to 25000.

1. GEOMETRIC DESIGNING PARAMETERS AND ALIGNMENT DESCRIPTION

This topic deals with geometrical standards adopted for horizontal and vertical alignments, route description, etc. The proposed corridors under Phase I network will consist of Standard Gauge (SG) lines. For underground corridors, track centres are governed by spacing of tunnels and box design. The geometrical design norms are based on international practices adopted for similar metro systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 80kmph. Planning for any higher speed is not desirable as the average inter-station distance is about 1.06 km and trains will not be able to achieve higher speed. The elevated tracks will be carried on box-shaped elevated decking supported by single circular piers or oblong piers, generally spaced at 31 m to 34 m centres and located on the median of the road to extent possible over road. The horizontal alignment and vertical alignment are, therefore, dictated to a large extent by the geometry of the road and ground levels followed by the alignment over road. The underground tracks will be carried in separate tunnels to be drilled by Tunnel Boring Machine. Stations will, however, be constructed by cut and cover method except one station which has been proposed by NATM with TBM going through.

2. GEOMETRIC DESIGN PARAMETERS

The design parameters related to the Metro system described herewith have been worked out based on a detailed evaluation, experience and internationally accepted practices. Various alternatives were considered for most of these parameters but the best-suited ones have been adopted for the system as a whole.

A. Horizontal Alignment

As far as possible, the alignment follows the existing roads. This leads to introduction of horizontal curves. On consideration of desirable maximum cant of 110 mm and maximum permissible cant deficiency of 100 mm on Metro tracks, the safe speed on curves of radii of 400 m or more is 80 km/h. On elevated sections minimum radius of145m has been used at one location having speed potential upto 45 km/h. However in underground section desirable minimum radius of curve shall be 400 m for ease ofworking of Tunnel Boring Machine (TBM).

Horizontal Curves

Desirable Minimum radius 400 m 400 m

Absolute minimum radius 200 m (only cut & cover)- 120 m

Minimum curve radius at stations 1000 m 1000 m

Maximum permissible cant (Ca) 125 mm 125 mm

Maximum desirable cant 110 mm 110 mm

Maximum cant deficiency (Cd) 100 mm 100 mm

B. Transition Curves

It is necessary to provide transition curves at both ends of the circular curves for smooth riding on the curves and to counter act centrifugal force. Due to change in gradients at various locations in the corridor, it is necessary to provide frequent vertical curves along the alignment. In case of ballast less track, it is desirable that the vertical curves and transition curves of horizontal curves do not overlap. These constraints may lead to reduced lengths of transition curves at certain locations. The transition curves have certain minimum parameters:

- Length of Transitions of Horizontal curves (m) Minimum : 0.44 times actual cant or cant deficiency (in mm), whichever is higher. Desirable : 0.72 times actual cant or cant deficiency, (in mm), whichever is higher.
- Overlap between transition curves and vertical curves not allowed.
- Minimum straight between two Transition curves (in case of reverse curves): either
25 m or Nil.
- Minimum straight between two Transition curves (in case of same flexure curves):
either 25 m or both curves should be converted in to the compound curve by
introducing single transition between the two circulars.
- Minimum curve length between two transition curves: 25 m

C. Vertical Alignment and Track Centre

(a) Elevated Sections

The viaducts carrying the tracks will have a vertical clearance of minimum 5.5 m above road level. For meeting this requirement with the 'Box' shaped pre-stressed concrete girders, the minimum rail level will be about 9.8 m above the road level. However, at stations which are located above central median, the minimum rail level will be 11.8 m above the road level with concourse at mezzanine. These levels will, however, vary marginally depending upon where the stations are located. At special continuous span locations the minimum rail level will be 11. 6m. For N-S alignment passing over railway land, in addition to the above requirement for service road, SOD of double stack container (as per DFCC western corridor) is also to be followed. A minimum clearance of 5.5 m for road traffic over proposed road surface for ROB ramp for Shyamaprasad Mukharji ROB and proposed road surface for Shreyas and Ellis Bridge ROB is to be maintained. The proposed road surface of these ROBs will be decided based on the SOD for double stack container movement. The track centre on the elevated section is kept as 4.2 m uniform throughout the corridor to standardize the superstructure, except at few locations, wherever scissors crossovers are planned, it is kept 4.5 meter.

(b) Underground sections

Rail level at midsection in tunneling portion shall be kept at least 12.0 m below the ground level. At stations, the desirable depth of rail below ground level is 13.5 m, so that station concourse can be located above the platforms. Track center in underground sections are follows:

Track center in underground sections are follows:

Sections where stations are to be constructed by cut & cover and running section by TBM to Accommodate 13 m wide platform 16.04 m (for lesser width of platform, track center to be reduced) Sections where stations are to be constructed by NATM and running section by TBM to facilitate Construction of stations 23.04 m Sections where stations as well as running section both are to be constructed by cut and cover method4.50 m

(c) Gradients

Normally the stations shall be on level stretch. In exceptional cases, station may be on a grade of 0.1 %. Between stations, generally the grades may not be steeper than 3.0 %. However, where existing road gradients are steeper than 2% or for Switch Over Ramps gradient up to 4% (compensated) can be provided inshort stretches on the main line.

(d) Vertical Curves

Vertical curves are to be provided when change in gradient exceeds 0.4%. However, it is recommended to provide vertical curves at every change of gradient.

(e) Radius of vertical curves:

• On main line (desirable) : 2500 m

(Absolute minimum) : 1500 m

• Other Locations : 1500 m

• Minimum length of vertical curve : 20 m