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MANUAL FOR GRADE SEPARATORS & ELEVATED STRUCTURES

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MANUAL FOR GRADE SEPARATORS AND ELEVATED STRUCTURES

1 INTRODUCTION

On account of phenomenal growth of vehicle population on both highways and urban areas, there is an increasing demand to eliminate traffic bottlenecks at road intersections by providing grade separated structures for safe passage of pedestrians and vehicles. Such structures segregate traffic moving in different directions at road intersections and are also known as flyovers, underpasses/over passes. The ROB/RUB and LHSs are also grade separated structures for free passage of highway traffic across Railway lines.

The General Design Features (Bridges & Grade Separated Structures (B-1) Committee was constituted in 2009 with the following personnel:

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Agrawal, K.N.	Co-Convenor
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The revised draft was approved by Bridges Specifications & Standards Committee in its meeting held on 1.5.2010 and subsequently, the Executive Committee approved the same in its meeting held on 10.5.2010 and authorized Secretary General, IRC to place the same before the Council.The modified document was approved by the IRC Council in its meeting held on 22.5.2010 at Munnar (Kerala) for printing.

2 SCOPE

This Manual covers various aspects and practices required to be considered in the Planning, Design, Construction and Maintenance of all the forms of grade separated structures including Flyovers, ROBs, RUBs, Underpasses, Subways, Pedestrian or Foot Over Bridges and Interchanges both for urban as well as rural or non-urban situations. The requirements and provisions of this Manual may be followed wherever applicable, except in cases where local site conditions, byelaws or other regulations require otherwise.

The relevant provisions of the IRC Codes will prevail for these structures also.

These structures shall be provided only at locations where the volume and intensity of traffic has become excessive of the capacities, defined in subsequent Chapters of level traffic managements systems, e.g., signals, railway gates, rotaries and split rotaries etc. or where otherwise required from various other considerations or part of future planning. The shape, form and arrangement of the grade separator system shall be decided as per the guidelines given in this Manual.

3 REFERENCE OF IRC AND OTHER CODES

IRC Codes generally deal with river bridges as well as land based bridges & flyovers. Several provisions related with water flow contained in IRC Codes will, therefore, not be applicable for Grade Separators. Conditions of exposure, loading and dynamic effects due to fast moving vehicles make these structures quite different than river bridges and other structures. Hence, grade separators and Elevated Structures require some other considerations in their planning and design. The following IRC and other Codes, however, are relevant:

IRC:5	-	Standard Specifications and Code of Practice for Road Bridges, Section - I General Features of Design (Seventh Revision)
IRC:6	-	Standard Specifications and Code of Practice for Road Bridges, Section II - Loads and Stresses (Fourth Revision)
IRC:9	-	Traffic Census on Non-Urban Roads (First Revision)

IRC:11	-	Recommended Practice for the Design and Layout of Cycle Tracks
IRC:18	-	Design Criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete) (Third Revision)
IRC:21	-	Standard Specifications and Code fo Practice for Road Bridges, Section III - Cement Concrete (Plain and Reinforced) (Third Revision)
IRC:22	-	Standard Specifications and Code of Practice for Road Bridges, Section VI - Composite Construction (Limit States Design (Second Revision)
IRC:24	-	Standard Specifications and Code of Practice for Road Bridges, Section V - Steel Road Bridges (Limit State Method (Third Revision)
IRC:54	-	Lateral and Vertical Clearances at Underpasses for Vehicular Traffic
IRC:69	-	Space Standards for Roads in Urban Areas
IRC:70	-	Guidelines on Regulation and Control of Mixed Traffic in Urban Areas
IRC:78	-	Standard Specifications and Code of Practice for Road Bridges, Section VII - Foundations and Substructure (Second Revision)
IRC:73	-	Geometric Design Standards for Road (Non-Urban) Highways
IRC:86	-	Geometric Design Standards for Urban Roads in Plains
IRC:87	-	Guidelines for the Design and Erection of Falsework for Road Bridges
IRC:92	-	Guidelines for the Design of Interchanges in Urban Areas
IRC:103	-	Guidelines for Pedestrian Facilities
IRC:104	-	Guidelines for Environmental Impact Assessment of Highway Projects
IRC:106	-	Guidelines for Capactiy of Urban Roads in Plain Areas
IRC:SP:23	-	Vertical Curves for Highways
IRC:SP:35	-	Guidelines for Inspection and Maintenance of Bridges
IRC:SP:41	-	Guidelines on Design of At-Grade Interesctions in Rural & Urban Areas
IRC:SP:42	-	Guidelines on Road Drainage
IRC:SP:47	-	Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
IRC:SP:50	-	Guidelines on Urban Drainage
IRC:SP:51	-	Guidelines for Load Testing for Bridges
IRC:SP:54	-	Project Preparation Manual for Bridges
IRC:SP:64	-	Guidelines for the Analysis and Design of Cast-in- Place Voided Slab Superstructure

IRC:SP:64	-	Guidelines for Design and Construction of Segmental Bridges
IRC:SP:66	-	Guidelines for Design of Continuous Bridges
IRC:SP:69	-	Guidelines & Specifications for Expansion Joints
IRC:SP:70	-	Guidelines for the Use of High Performance Concrete in Bridges
IRC:SP:71	-	Guidelines for Design and Construction of Pre-tensioned Girder of Bridges
MORT&H	-	Pocketbook for Bridge Engineers, 2000 (First Revision)
MORT&H	-	Pocketbook for Highway Engineers, 2002 (Second Revision)
MORT&H	-	Type Designs for Intersections on National Highways, 1992
HRB SR. No. 16	-	State of the Art: Reinforced Soil Structures Applicable to Road Design & Construction
BS : 8006:1995		Code of Practice for Strengthened/reinforced soils and other fills.

4 DEFINITIONS

Following definitions shall be applicable:

4.1 Bridge

Bridge is a structure for carrying the road traffic or other moving loads over a depression or obstruction such as channel, river, road or railway.

4.2 Foot Over Bridge

The foot over bridge is a bridge exclusively used for carrying pedestrians, cycles and animals.

4.3 Grade Separator

Grade separator is a form of intersection in which one or more conflicting movements on intersecting ground transport facility such as road, rail, pedestrian way or cycle path are segregated in space. Flyover, Railway over bridges, under bridges, subways and under passes both for vehicular and pedestrian traffic are all grade separators and will be reckoned as such.

4.4 Clearance

Clearance is the minimum vertical or horizontal distance between boundaries at a specified position of a bridge structure/grade separator available for passage of vehicles.

4.5 Length of Bridge

The length of a bridge structure will be taken as the overall length measured along the centre line of the bridge from end to end of the bridge from face to face of dirt wall.

4.6 Approach

A part of road which connects the existing road to the abutment of the bridge on each side.

4.7 Road Over Bridge - ROB

A bridge over the rail line for the purpose of crossing it without interruptions with approaches on both sides is commonly called as Road Over Bridge - ROB.

4.8 Flyover

A bridge over another road for allowing cross traffic without interruption with its approaches on both sides is commonly called as Flyover.

4.9 Viaduct

Portion of approaches on stilts for affecting economy in cost of construction or for providing opening in part of the approach of ROB or Flyover in place of solid earth filled embankment with or without return walls for allowing cross traffic or for use of space below for godown, office shops and such uses.

4.10 Road Under Bridge

Generally used for a bridge which carries rail lines or other services above the road.

4.11 Under Pass, Subway

Underpass is a structure allowing movement of traffic beneath a roadway. An underpass is sub classified as cattle underpass, pedestrian underpass and vehicular underpass depending on the principal user.

Subway is usually for pedestrian crossing below roadway.

4.12 Safety Kerb

A safety kerb is a roadway kerb widened to provide for occasional pedestrian refuge.

4.13 Super-elevation (Cant or Banking)

Super-elevation is the transverse inclination given to the cross-section of a carriageway at a horizontal curve in order to reduce the effects of centrifugal force on a moving vehicle.

4.14 Width of Footway or of Safety Kerb

The width of footway or of safety kerb shall be taken as the minimum clear width anywhere within a height of 0.225 meters above the surface of the footway or safety kerb. Such width is measured at right angles to the centre line of the bridge.

4.15 Width of Roadway

The width of roadway is the minimum clear width measured at right angles to the longitudinal centre line of the bridge between the inside faces of roadway kerbs or wheel guards.

4.16 Straight Ramps or Loop Ramps

An inter-connecting roadway or any connection between highways at different levels, or between parallel highways, on which vehicles may enter or leave a designated roadway. The components of ramp are a terminal at each end and a connecting road, usually with some curvature and on a grade.

4.17 Interchange

An interchange is a grade separated intersection with connecting roadways (ramps and loops) for turning traffic between highway approaches.

4.18 Lateral Clearance

Lateral clearance is the distance between the extreme edge of the carriageway to the face of the nearest support whether it is a solid abutment, pier or column.

4.19 Vertical Clearance

Vertical clearance stands for the height above the highest point of the traveled way, i.e., the carriageway and part of the shoulders meant for vehicular use, to the lowest point of the overhead structure.

4.20 Non Urban Roads

Non-urban roads in the country are (i) Expressways (ii) National Highways (NH), (iii) State Highways (SH), (iv) Major District Roads (MDR), (v) Other District Roads (ODR), (vi) Village Roads (VR).

4.21 Service Road (SR)

A Service Road is an auxiliary road that runs parallel to a controlled access highway that provides access for the adjoining property at a few selected places.

4.22 Urban Roads

Urban roads are classified into the following five categories:

i) ***Elevated Highways:*** The function of elevated highways is to cater for fully or partially access controlled movement of heavy volumes of motor traffic at high speeds. They connect major points of traffic generation and are intended to serve trips of medium and long length between large residential areas, industrial or commercial concentrations and the central business district. They are divided highways with high standards of geometrics and full or partial control of access. Parking, loading and unloading of goods and passengers are not permitted on these highways.

ii) ***Arterial Streets:*** This system of streets, along with expressways where they exist, serves as the principal network for through traffic flows. Significant intra-urban travel such as between central business district and outlying residential areas or between major sub-urban centers takes place on this system. These streets may generally be spaced at less than 1.5 km in highly developed central business areas and at 8 km or more in sparsely divided highways with full or partial access. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections.

iii) ***Sub-arterial Streets:*** These are functionally similar to arterial streets but with somewhat lower level of travel mobility. Their spacing may vary from about 0.5 km in the central business district to 3-5 km in the sub-urban fringes.

iv) ***Collector Streets:*** The function of collector streets is to collect traffic from local streets and feed it to the arterial and sub-arterial streets or vice-versa. These may be located in residential neighbourhoods, business areas and industrial areas. Normally, full access is allowed on these streets from abutting properties. There are few parking restrictions except during the peak hours.

v) ***Local Streets:*** These are intended primarily to provide access to abutting property and normally do not carry large volumes of traffic. Majority of trips in urban areas either originate from or terminate on these streets. Local streets may be residential, commercial or industrial, depending on the predominant use of the adjoining land. They allow unrestricted parking and pedestrian movements.

4.23 Speed

It is the rate of motion of individual vehicles of a traffic stream. It is measured in meters per second, or more generally as kilometers per hour. Two types of speed measurements are commonly used in traffic flow analysis; viz. (i) Time mean speed and (ii) Space mean speed. For the purpose of these guidelines, the speed measure used is “Space mean speed”.

4.24 Time Mean Speed

It is the mean speed of vehicles observed at a point on the road over a period of time. It is the mean spot speed.

4.25 Space Mean Speed

It is the mean of vehicles in a traffic stream at any instant of time over a certain length (space) of road. In other words, this is average speed based on the average travel time of vehicles to traverse a known segment of roadway. It is slightly less in value than the time mean speed.

4.26 Volume (or Flow)

It is the number of vehicles at a given point on the road during a designated time interval. Since roads have a certain width and a number of lanes are accommodated in that width, flow is always expressed in relation to the given width (i.e. per lane or per two lanes etc.). The time unit selected is an hour or a day. ADT is the Average Daily Traffic when measurements are taken for a few days. AADT is the Annual Average Daily Traffic when measurements are taken for 365 days of the year and averaged out.

4.27 Density (or Concentration)

It is the number of vehicles occupying a unit length of road at an instant of time. The unit length is generally one kilometer. Density is expressed in relation to the width of the road (i.e. per lane or per two lanes etc.). When vehicles are in a jammed condition, the density is maximum. It is then termed as the jamming density.

4.28 Capacity

It is defined as the maximum hourly volume (vehicles per hour) at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions.

4.29 Design Service Volume

It is defined as the maximum hourly volume at which vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under the prevailing roadway, traffic and control conditions while maintaining a designated level of service.

4.30 Peak Hour Ratio

It is defined as the traffic volume during peak hour expressed as a percentage of the AADT. The peak hour volume in this case is taken as the highest hourly volume based on actual traffic counts.

5 PLANNING

5.1 Collection of Data

The requirement of a grade separator, its shape, size, type and configuration at any location is decided by collecting sufficient relevant data and information and analyzing it with respect to volume, intensity and type of traffic, loadings, climatic conditions and geotechnical investigations, space restraints and limitations because of underground and overhead utilities services and available geometrics, traffic regulation during construction etc.

All this data as discussed subsequently, should be collected and then studies and investigations should be properly and adequately done for deciding the various parameters for planning, layout, design and construction and maintenance etc.

5.2 Organizations Involved

Construction of a grade separator through a town will affect buildings and other structures and encroachments, electrical services, underground telephone lines, water mains and sewer lines etc. These services are maintained by different departments and therefore, they are to be contacted for collection of the data and information concerning to them. This requires lot of efforts and time in coordination of this activity.

Formation of a coordination committee headed by a development/coordination authority may be helpful to render assistance in collecting the relevant data and in solving various problems connected with removal, replacement or shifting of these expeditiously.

It may also be necessary to stop or divert traffic requiring assistance from police or other regulatory agencies.

In case of railway over bridges, coordination with railway authorities is necessary.

Generally, coordination with following authorities will be necessary:

- Revenue Department : Acquisition of land/buildings or removal of encroachments.
- Police : Traffic control
- Municipal Corporation : Water lines, sewer lines
- Authorities like Public Works Department (PWD), Public Health Engineering Department (PHED), Water Boards & Development Authorities or Improvement Trusts : Storm Water Drains, Roads, Lands
- Telecommunication : Telephone lines
- Railways : In case of ROB
- Transport Departments : Traffic data
- Town Planning : To keep in view the Master Plan/Development Plan of the area while deciding layout of approaches.
- Electricity Board : For electric lines, street lights
- Gas Authorities : For Gas Pipe lines
- Urban Arts Commission etc. : For urban planning and aesthetic considerations
- Environment Control Agencies : For environmental, rehabilitation and pollution control clearances
- Fire and Safety Organizations : For safety clearances
- NGOs : For R & R issues
- Forest Deptt or Concerned : For tree cutting etc.
- Central Govt. Agencies

- ASI /Heritage Department etc : For clearances if affecting monuments or heritage zones
- Irrigation Department : Canal Bridges, Tanks, Tube Well, Ghats, etc.
- Other regulatory bodies or organizations (which may be affected/ connected directly or indirectly)

5.3 Index Map Showing the Location

An Index map to a suitable small scale (topo sheets scale 1 cm equal to 500 m or 1/50000 would do in most cases) showing the proposed location of the grade separator, the alternative sites investigated and rejected, existing means of communications, the general topography of the country and the important towns in the vicinity, bus stops, schools, religious places and most preferred crossing points, etc.

5.4 Study of Master Development Plan of the Area

The Master development plan of the area where the grade separator is to be constructed or any other schemes, already planned or being planned, in the vicinity affecting the project should be studied in detail. Its impact, if any, on the planning and detailing of grade separator should be assessed and accounted for.

5.5 Surveys-Site Plan/L-Sections/Cross-Sections

Site Plan:

A site plan to a suitable scale shall be prepared. It shall contain the following:

- The alignment of the existing approaches and of the proposed crossing and its approaches.
- Location of nearest junction on either side with distance.
- The name of the nearest inhabited identifiable locality at either end of the crossing on the roads leading to the site.
- Reference to the position (with description and reduced level) of the bench mark used as datum.
- The location of trial pits or borings, each being given an identification number and connected to the datum.
- The location of all nallahs, buildings, wells, outcrops of rocks and other possible obstructions to a road alignment.
- Other connecting main road of the town and roads going outside town and distance from proposed grade separator.
- All service lines and utilities must be shown in the plan.

L-Section:

L-Section along approved alignment.

5.6 Traffic Studies

For detailed planning of such facilities which have to be related to the desired level of service along such corridors, it becomes necessary to study, in detail, the present and expected future characteristics of traffic at such locations. The following surveys are required to be carried out for making these studies :

- Road Inventory Survey
- Classified Traffic Volume Survey
- Turning Movement Count Survey
- Vehicle Occupancy Survey
- Roadside Origin-Destination Survey
- Vehicle Speed and Delay Survey
- Intersection Volume - Delay Survey

5.6.1 *Road inventory survey*

Road Inventory Survey provides the details of road and street network. Enumerators collect the information on the field sheets which are maps drawn in a large suitable scale. A typical survey party consists of a party leader (one), observer and recorder (one) and tape holders (two). The typical information collected from road inventory survey are :

- Width of Carriageway
- Width of Footpath
- Location of Traffic Signal Posts
- Location of Traffic Signs/Advertising Boards
- Location of Bus Stops/Shelters
- Width of Central Divider
- Location of Lamp Poles
- Location of Manholes
- Whether Footpaths/Carriageway Encroached by Hawkers/Stall/Others
- Schools, Religious Places, Most Preferred Crossings.
- Obstructions Due to Existing Utilities/Services

5.6.2 *Classified traffic volume survey*

Classified volume establishes the magnitude of traffic by different types of vehicles for each hour of the day. Classified Traffic Volume Survey can be carried out manually as well as with the use of automatic traffic counters. By utilizing the data obtained from permanent traffic counting stations, 24 hours traffic volume can be expanded for any particular day, month or season to a representative annual average daily traffic (ADT) volume. ADT volumes are used for evaluation of traffic flow with respect to the existing roadway system measurement of present-demand for service by roadway and planning of location of new facilities, new route selection and evaluation of alternative traffic management actions.

5.6.3 *Turning movement count survey*

Turning movement counts at junctions are important for the design of junction, channelization, capacity analysis, traffic signal timing and phasing, turn lanes, parking and turning restrictions. Turning movement counts should be conducted manually and recorded in 15 minutes interval according to lane movement and by vehicle classification. Peak hours (morning and evening) are sufficient for most of the situations. Standard forms are used for data collection for turning movement count survey.

Turning movement surveys at complex intersection:

At complex intersections where the turning movement will be difficult to observe, particularly at rotaries, recording of the registration number plate will be used for collection of the base turning movement data at site during 8 hours dividing into 4 hours each, during the morning and evening peak periods, so as to cover the peak traffic during morning and evening periods.

The data analysis methodology for turning count surveys will be as per guidelines stipulated in IRC:SP:41.

5.6.4 *Vehicle occupancy survey*

Vehicle occupancy survey determines the occupancy of passengers in each vehicle. This survey establishes the traffic volume in terms of number of persons by different types of vehicle crossing at a given point. The analysis of vehicle occupancy survey data and junction delay survey data provide valuable inputs in economic analysis of the project.

5.6.5 *Roadside origin and destination survey for non-urban roads*

Origin-destination surveys are designed to identify the travel pattern and thus allow transport planners to analyze the existing traffic pattern and project future transportation requirements. A study is made of the daily travel characteristics by taking sample of all travelers. A cordon is established around the study area. Depending upon the objective of the study, questionnaires are prepared and questions are asked from a sample of people entering/leaving the cordon. Generally, the question include origin and destination of their trips, trip purpose, trip time, frequency of trips etc. The survey data is coded and then computerized. The computer analysis of the data assists the transport planner to project inter-zonal movements, mode preference and desires of particular population. This study should be made on need basis depending upon complexity of the grade separator.

5.6.6 *Vehicle speed and delay survey*

Vehicle speed-delay survey is necessary for economic studies such as, cost-benefit analysis for transport facilities. Congestion can be evaluated by means of speed and delay studies. There are several methods which can be used for speed-delay survey. These are:

Test car method

License plate method

- Estimate of volume and travel time using moving vehicle
- Interview method

Test car method is generally recommended because of proven reliability and simplicity. The "average speed" technique using this method is one in which the driver of a test vehicle travels at the speed that in his opinion is representative of all traffic at that time. An observer seated in the vehicle utilizes two stop watches for timing purposes. The first watch is started at the beginning of the test run and records the time at various control points along the route. The second watch is used to measure the length of individual stopped time delays. The time, location and cause of these delays are recorded either on forms or by voice recording equipment. The data is summarized and filed by road segment. Speed maps can be prepared showing morning, evening and off-peak speeds for each road segment under the study. The survey data could be easily computerized for further analysis.

5.6.7 *Intersection volume-delay survey*

The Intersection volume delay survey is conducted at any intersection of interest to provide a detailed evaluation of the stopped time delay of either vehicular or pedestrian traffic. For justification of grade separator, intersection volume-delay survey is a must. The application of the information could also be made for the development of proper timing sequences for traffic signals, calculation of delay costs in the economic analysis of highway and traffic improvements and evaluation of geometrics that are critical in intersection design.

Sampling procedure is to be used for stopped time delay method. This involves the counting of the number of vehicles stopped in the intersection approach at successive intervals. This sampling along with volume count (during the same time observations are made) permits estimating the vehicle stopped time delay. As a guide, sampling interval should not be an even subdivision of cycle length. The study team consisting of seven members positions itself at one of the four approaches of an intersection, records the data for a six minute duration (also six such consecutive observations) then rotates to next approach till all approaches are covered.

5.7 Deciding the Type of Facility

Grade separators essentially segregate traffic in space and depending upon prevailing and expected traffic characteristics, present and proposed development plans for the area, site constraints and environmental considerations, could take various forms.

The type and classification of the grade separated facilities to be provided at any particular junction or crossing will mainly depend on the following factors:

- i) Location Attributes- whether in open areas or habitated or urban areas
- ii) Traffic requirements based on the interpretation and analysis of traffic studies made and data collected
- iii) Future development plans
- iv) Roadway Classification and Capacity
- v) Level of service required
- vi) Local restraints – ROW, underground and above ground utilities and services and environmental issues
- vii) Design and construction requirements

The importance of roads and volume of traffic on them will usually decide which one would remain at level and which one would fly over the other. Lesser important and lower traffic volume roads should fly over the other unless there are some specific considerations or constraints.

5.7.1 *Location attributes*

Generally speaking flyovers in open areas are not confronted with the same degree of site constraints as in the case of flyovers in town/urban areas. It is mainly because of this reason that flyovers/grade separators in open areas tend to take more liberal forms than those in urban areas.

5.7.1.1 Flyovers in open areas

Planning of flyovers in open areas is essentially guided by considerations of level of service that is expected along the designated corridor. The hierarchical pattern of road network along with hierarchical classification of cross roads usually decides the planning of flyovers in such areas.

Thus, it may be desirable to have grade separated facility at an intersection between two national highways or between a national highway and a state highway even though, the level of congestion may not immediately indicate the need for such a facility. This is because of the operational attributes that are associated with traffic operation along national highways.

By definition, an expressway is expected to have only grade separated intersections and as such, provision of such treatments along an expressway becomes an integral part of even the preliminary planning process. However, since detailed planning of such facilities will have to be related to the desired level of service along such corridors it becomes necessary to study, in detail, the present and expected future characteristics at such intersections.

By their location attributes, intersections in open areas usually cater largely to long haul through and intercity traffic that may not show any distinct and repetitive peaking characteristics. In order to obtain an accurate estimate of the design year traffic volumes, traffic surveys must be conducted at such locations for 24 hours over seven consecutive days. The survey should be designed in such a manner that category wise traffic counts and turning characteristics of traffic at intersections are adequately covered. The average of seven days of traffic volumes will give the Average Daily Traffic (ADT) that has to be subsequently corrected for seasonal variations with the help of data available for different seasons from permanent count stations maintained by the state PWD. Even if such permanent count station data are not available for the intersection under consideration, a well judged estimate of the same could be made from data available for nearby count stations that might experience similar fluctuations in traffic volumes as would be expected at the intersection under study. Also, monthly fuel rates data collected from the outlets of nearby areas can be used for arriving at correction factors separately.

In case, Average Annual Daily Traffic (AADT) calculated over 365 days a year is available for the base year such data would also be made use of in the planning process. The ADT or the AADT must however, be available with an hourly split up of traffic volumes.

For an existing intersection, data on intersection delays must be collected.This information becomes necessary for establishing the viability of the scheme.

Design traffic volume could be defined as that hourly volume of traffic by the design year for which the facility is to be planned. Usually, such a facility has a design life of 20 years after construction and as such, design traffic volume will refer to the design hourly traffic volume at the end of the design life. Determination of design hourly volume requires assessment of peak hourly traffic during the base year and projecting the same to the design year.

There are several ways of determining the peak hour traffic volume at the base year for flyovers in open areas. In the even of AADT being available to 30th highest hourly volume can be considered as the peak hourly volume of base year. Under circumstances where this is not available 12-14 percent of ADT could be taken as the peak hourly volume. In case, there is a distinct repetitive peak hour at a particular location, such peak hourly volumes may also be considered for further analysis.

Hourly traffic volumes are expressed in terms of equivalent passenger car units. The factors for equivalency for various categories of vehicles are given in **Table 1.** The base year peak hourly volume is to be projected to the design year with the help of growth factors that may be determined on the basis of trend analysis (if time series data are available), economic growth factors of the hinter land, growth factors related to Gross Domestic Product (GDP), or at a compound rate of 7.5 percent per annum (in absence of any other information).

The concept of level of service relates traffic volume levels to levels of efficiency of traffic operation under specified physical and other boundary conditions. In planning a high type facility like flyovers etc. it is important that the level of service of the proposed facility be defined before hand so that the design service volume is logically established. Design service volume at a particular level of service is that maximum volume of traffic which can be serviced by a facility at the design speed corresponding to the defined level of service. It must be understood that design service volume will be different under different levels of service conditions. In order words, design service volume under a particular level of service indicates capacity of the facility at that level of service. The cross-sectional requirements like number of lanes etc., could be easily determined by dividing the design hourly volume by the design service volume.

5.7.1.2 Flyovers in urban areas (urban flyovers)

Planning of urban flyovers is generally guided by considerations of safety, efficiency and economy of traffic operation across major intersections along important road corridors. Unlike flyovers in open areas, planning of such facilities in urban areas is very frequently guided by space constraints, constraints of underground and over head services, environmental considerations, aesthetics and urban design norms. One has to also keep in view the city and its corridor layout pattern while planning a flyover in an urban area. Intersections are usually fairly closely spaced in a city and while planning a flyover at an intersection, the impact of the facility on the adjoining intersections must also be suitably assessed. While hierarchical pattern of road network remains an important factor in planning urban flyovers, the traffic characteristics at the intersection remain the most important decisive factor to this effect. Traffic studies thus become a key activity in the context of planning of flyovers in urban areas.

Traffic facilities in urban areas are usually planned for catering to peak hour traffic demands. It is thus very important to identify the peak hour and the peak hour traffic characteristics at such urban intersections.

The decision to provide a flyover shall be based on examination of different alternatives and only after all other avenues of efficient management of traffic through grade treatments are exhausted. It must also be remembered that an urban flyover would generally serve the fast traffic (including buses) and thus, composition of traffic at such locations must also be carefully studied and evaluated.

Traffic volume surveys for intersections in urban areas should be carried out for 24 hours on an average working day at 15 minutes interval so as to elicit information on hourly traffic volumes including the morning, mid day and evening peak hour traffic volumes. This should also clearly bring out the turning characteristics of traffic at the intersection and the composition of traffic. In case, there are other intersections within the close vicinity of the intersection under study, it would be a good idea to carry out traffic survey at such locations as well. The peak hour traffic volumes will be ultimately expressed in terms of equivalent passenger car units with the help of factors of equivalency.

Speed and delay survey are considered very important towards justifying provision of flyover at an urban intersection. The data to be collected under this would relate to signal cycle time (if the intersection is signalized), average delay at the intersection and average stream speed over the influence area.

Other information to be collected in connection with design of flyovers in urban areas would include information on bus routes and locations of bus stops, hourly volumes of pedestrians crossing the intersection approach arms (at least for 12 hours on an average working day), overhead and underground services and development plans, if any, for the adjacent quadrants.

As in the case of flyovers in open areas, the design traffic volumes for urban intersections will be the projected peak hourly volume at the end of the design life of the facility (20 years after the construction of the flyover). Determination of design peak hourly volume requires assessment of peak hour traffic during the base year and projecting the same in the design year.

The base year peak hour traffic volume in this case is determined through traffic surveys. However, projecting the traffic to the design peak hour volume is a complex process and has to be attempted following several methods of projection. For such purposes the master plan of the city and its perspective development plan must be referred to in order to find out the expected pace of urban development within the design life of the facility. Traffic generation norms as adopted in the master plan could then be applied to find out the additional traffic demand that would be generated at the intersection under consideration during its design life. It is possible that in certain cases only projected person trips would be available. In such instances person trips will have to be rationalized in terms of equivalent passenger car units through application of modal split. In certain cities growth factors for peak hour traffic in terms of PCU have already been established. In such cases determination of design peak hour volume becomes considerably easy.

Unless otherwise specified, a properly designed four arm intersection controlled by a traffic rotary (with six lane approaches) could be assumed to have maximum capacity of 5000 PCU during the peak hour. A similar intersection controlled by automatic traffic signals could have a maximum peak hour capacity upto 7500 PCU. Intersection traffic volumes nearing 10,000 PCU usually result in very inefficient and hazardous traffic conditions and it is at this level of traffic that provision of flyovers generally becomes necessary.

Traffic Surveys are thus necessary to establish quantitative information on traffic characteristics in terms of overall traffic volume, composition of traffic, hourly distribution, vehicle occupancy, average speed on road network and delay at junctions, origins and destination of trips etc. and road characteristics in terms of width of carriage-way, available right of way, number of traffic lanes, parking, location of traffic signs, bus stops and lamp poles, width of footpaths, encroachment etc. Analysis of traffic survey data provides valuable inputs for economic and financial analysis of grade separators and thus provides the basis for the justification of grade separators.

If a long section of road is intended to be developed as a fast corridor and even if few junctions of this corridor do not qualify for grade separator on account of minimum PCU, in such a situation the minimum PCU requirement may not come in the way of extending/constructing the flyover over these intersections.

5.8 Level of Service (LOS)

5.8.1 Level of Service is a qualitative measure describing operational conditions within a traffic stream and their perception by drivers/passengers.

5.8.2 Level of Service definition generally describes these conditions in terms of factors such as speed and travel time, freedom to manoeuver, traffic interruptions, comfort, convenience and safety. Six levels of service are recognized commonly, designated from A to F, with Level of Service A representing the best operating condition (i.e. free flow) and Level of Service F the worst (i.e. forced or break-down flow). On urban roads, the Level of Service is affected strongly by factors like the heterogeneity of traffic speed regulations, frequency of intersections, presence of bus stops, on street parking, roadside commercial activities, pedestrian volumes etc. This renders the Level of Service concept for urban roads somewhat different than the rural roads.

5.8.3 Capacity standards are fixed normally in relation to the Level of Service (LOS) adopted for the design.

5.9 Alignment and Layout

The alignment and lay out of a grade separator is usually determined by the alignments of the intersecting roads or traffic, plan area available and all the geometrical standards and other local restraints or site conditions.

However, wherever possible, the alignment and layout should avoid passing or covering congested areas or locations with too much of above and under ground utilities services or where meeting out the requirements of the geometrical standards and other requirements of this manual is not possible.

Alignment and layout should be fixed taking maximum advantage of the local topographical conditions and contours such that proper landscaping, smooth and pleasing elevation of the structures, openness, drainage and easy flow of traffic is possible giving pleasing aesthetical and environmental friendly effects.

5.10 Geometric Configuration

5.10.1 The type of grade separation and interchange, along with its design, is influenced by many factors, such as highway classification, character and composition of traffic, design speed and degree of access control. These controls plus design requirements, economics, terrain and right-of-way are of great importance in planning these facilities with adequate capacity to safely accommodate the traffic demands.

5.10.2 Simple grade separators are provided when the high volume traffic is to be segregated by the elevated structure . The rest of the traffic still passes at the level roads.

5.10.3 Interchanges, one level or multi level, are provided when several directional traffic is to be segregated from one another and all traffic is to be made signal free.

5.10.3.1 The ability to accommodate high volumes of traffic safely and efficiently through intersections depends largely on what arrangement is provided for handling intersecting traffic. The greatest efficiency, safety and capacity are attained when the intersecting through traffic lanes are separated in grades. An interchange is a system of interconnecting roadways in conjunction with one or more roadways or highways on different levels.

5.10.3.2 An interchange is a useful and an adaptable solution for many intersection problems, but because of the high initial cost, its use to eliminate existing conditions is limited to those cases where the required expenditure can be justified. An enumeration of the specific conditions or requirements justifying an interchange at a given intersection is difficult and in some instances cannot be conclusively stated. Because of the wide variety of site conditions, traffic volumes, highway types and interchange layouts, the requirements that justify an interchange may differ at each location. All the conditions should be considered to reach a rational decision at any location.

5.10.3.3 Each interchange site should be studied and alternate designs made to determine the most fitting arrangement of structures and ramps and accommodation of bicycle and pedestrian traffic through the interchange area. Interchanges vary from single ramps connecting local streets to complex and comprehensive layouts involving two or more highways.

5.10.4 *Justification for interchanges*

Interchanges, in general, are expensive to construct and a major factor influencing the cost is the type of arrangement made for the various traffic movement. The arrangement may range from separating only one traffic movement from other to the complete separation of each traffic movement from every other movement, so that only merging and diverging movements remain. Similarly, the vehicle operating cost will vary depending on the type of ramp arrangement, from direct conflict-free connections to indirect connections involving extra travel distance. As interchanges are custom designed to suit the prevailing conditions, it will be necessary to carry out cost benefit study taking into account the total transportation cost, i.e. the cost of construction, maintenance and vehicle operation, to evaluate the techno-economic merits of the individual cases before a final decision is taken. However, the following points may be helpful in guiding the choice of an interchange at the preliminary planning stage:

i) Interchange will be necessary at all crossings of a highway which is to be developed to completely access controlled standard. Similarly, interchanges will be required at all major crossings on highways developed to expressway standards.

ii) An interchange may be justified at the crossing of a major arterial road with another road of similar category carrying heavy traffic.

iii) An interchange may be justified when an at grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the inter-section. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.

iv) High and disproportionate rate of fatal and major accidents at an interaction not found to respond to other traffic control or improvement measure may warrant an interchange.

v) In some situations, the topography is such that interchanges are the only type that can be constructed economically.

vi) The requirement of interchange may also be justified from the existing constraints of the junctions other than traffic volume like parking, market, important and religious structures, buildings with frequent crowding.

vii) While planning interchange at a particular location the traffic requirements of the entire road on both sides should be taken into account.

5.10.5 *Types of ramps*

Interchanges are generally described by the pattern of the various turning roadways or ramps and loops which determine their geometric configuration. The ramps can be broadly classified into basic types, as described below:

i) Left turning roadway referred to as diagonal ramp or outer connection depending on its shape or type of interchange.

The direct ramp does not form a part of the trumpet interchange.

ii) A loop which is a ramp for right turns accomplished by a left exit and turn to the left through about 270 degree.

iii) Semi direct connection which is a ramp for right turns accomplished through a partial deviation from the intended path.

iv) Direct connection which is a ramp for right turns accomplished by a right directional and natural manoeuver involving least extra travel distance.

5.10.6 *Geometric configurations (common type)*

The common geometric configurations of interchanges are the trumpet, diamond, cloverleaf, rotary and directional . Within each type of interchange, there can be several variations such as split diamond, partial cloverleaf etc. depending on the ramp arrangements. The salient operational conditions for each of these interchanges are given below:

5.10.6.1 Trumpet interchange

A trumpet interchange is a 3-leg interchange. This is the simplest interchange form adaptable to "T" or "V" intersections. Of the two right turning movements, one is negotiated by a loop while the other is by a semi-direct connection. Diagonal ramps are provided for left turning movements. Several variations of the design are possible depending on the type of connection provided. The type of connection provided for the right turning movements should be based on traffic volumes. The ramps catering to heavy traffic volumes should preferably be provided with direct connections.

5.10.6.2 Diamond interchange

A typical diamond interchange is the simplest of 4-leg interchange designs and is particularly adaptable for major-minor highway intersections. The ramps which provide for one way movement are usually elongated along the major highway and may be curved or parallel to the major highway. The ramp terminals on the minor road are at grade intersections providing for right and left turning movements. Those at grade intersections may be controlled by signals if warranted by traffic volumes or in the absence of adequate sight distance.

5.10.6.3 Cloverleaf interchange

The design of a typical cloverleaf interchange consists of one loop ramp for right turning traffic and one outer connection for left turning traffic in each quadrant. Vehicles desiring to turn right are required to turn left through about 270 degrees before attaining the desired direction.

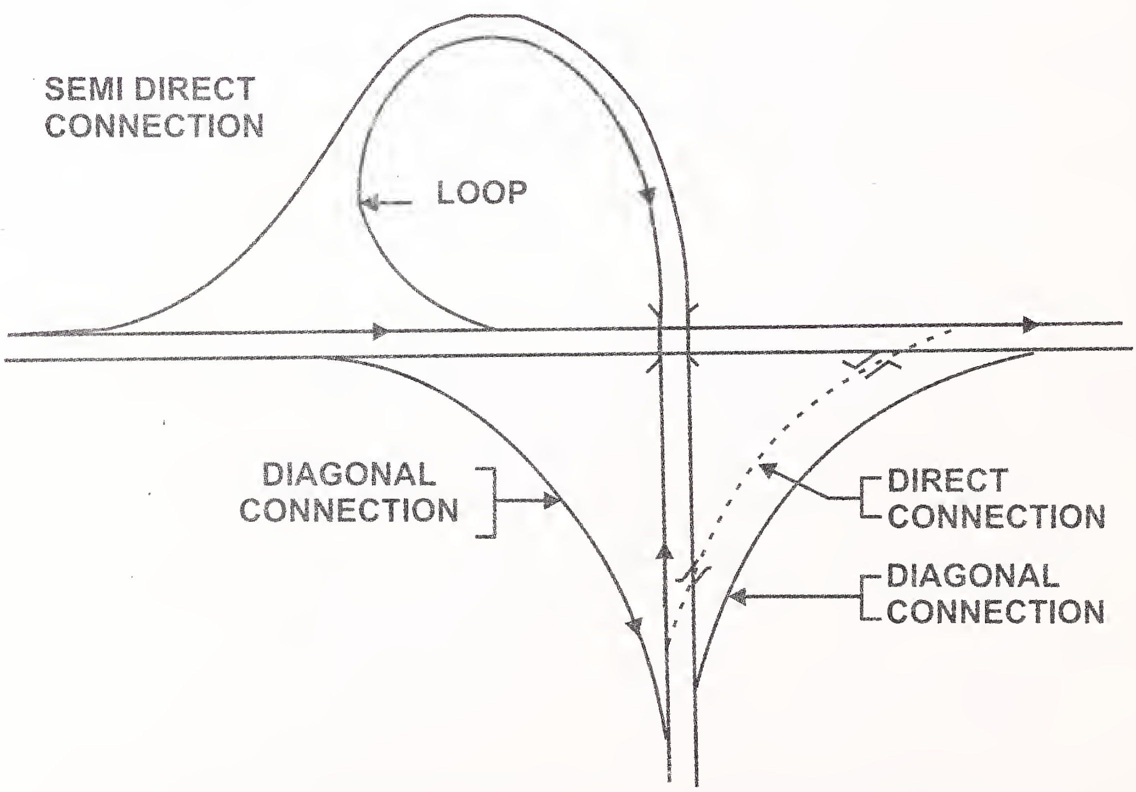
5.10.6.4 Rotary interchange

These are usually 4-leg interchanges. There can be variations depending on traffic requirement, site conditions, etc. This type of design is particularly useful where a number of roads intersect at the interchange and in locations where sufficient land is available. It requires the construction of two bridges and generally necessitates more land than for a diamond layout. The main highway goes over or under the rotary intersection and turning movements are accommodated by the diagonal ramps.

The capacity of a rotary interchange is similar to that of at-grade rotary. High speed operations cannot be maintained on the minor road because of the usually short weaving distances. It can, however, operate satisfactorily at low speeds. Also this type of design entails only a little additional travel distance for interchanging traffic which is a significant advantage when slow moving traffic is present.

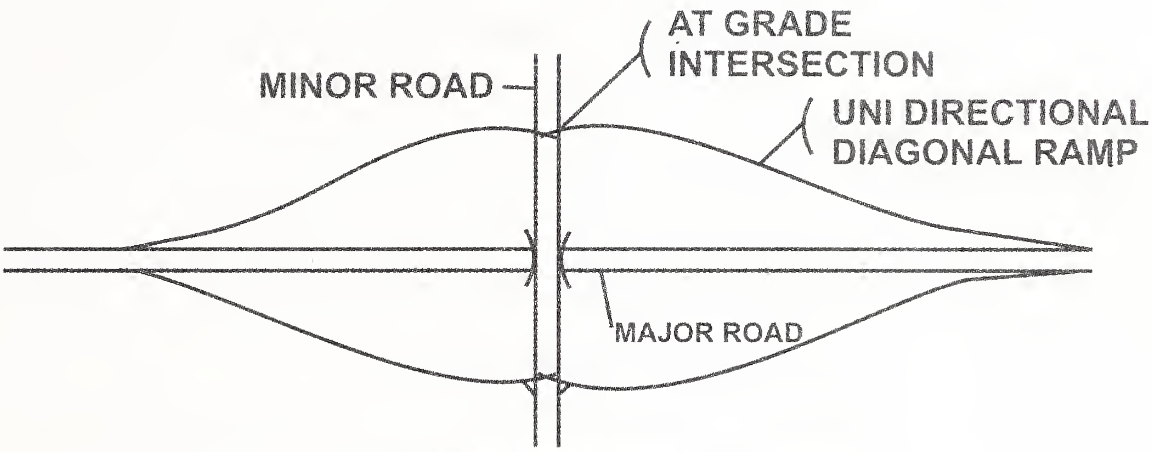
5.10.6.5 Directional interchange

Directional interchanges have ramps for right turning traffic which follow the natural direction of movement. This type of design requires more than one structure, or a 3-level structure. Though operationally more efficient than other designs, these generally turn out to be very expensive.

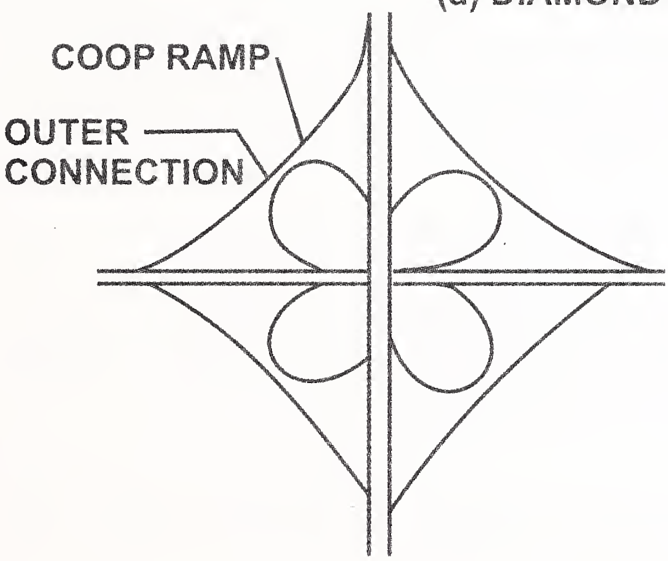


Typical Geometric Configurations Trumpet interchange

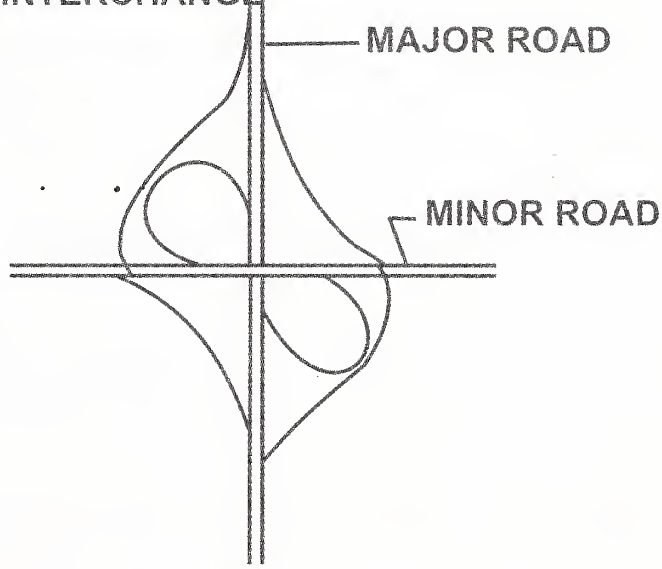
Note : The direct ramp shown doted is for illustrations and does not form a part of the trumpet interchange.



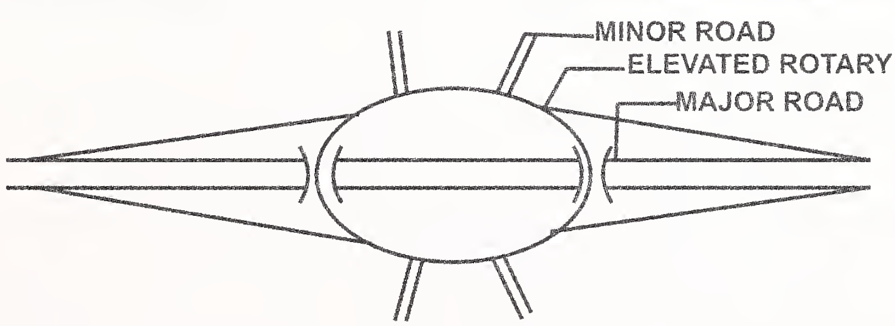
(a) DIAMOND INTERCHANGE



(b) FULL CLOVERLEAF



(c) PARTIAL CLOVERLEAF



(d) ROTARY INTERCHANGE

5.10.6.6 Land requirement

Approximate land requirements of interchanges are as below:

	Category	Approximate total land in hectares
1)	Trumpet interchange	4.4
2)	Diamond interchange	2.8
3)	Full cloverleaf	4.9
4)	Partial cloverleaf	7.3
5)	Flyover round about	18.0

5.10.7 *Desirable normal & acceptable standard*

Planning of grade separators and elevated structures in urban areas requires special consideration for fitting them within the constraints of the urban scenario. Very often Right-Of-Way (ROW) is restricted in a developed urban situation; both in the horizontal and vertical direction on both sides of ROW leading to curves which are beyond acceptable criteria of design codes. The vertical profiles are constrained due to the presence of traffic junctions very closely spaced to one another leading to gradients steeper than those permitted by prevalent design codes.

In such situations, especially in urban areas with sanctioned development plans, specific conditions may be required for the various geometric parameters and are summarized as being "Desirable", "Normal" and "Acceptable"

Desirable - which in the normal course must be executed on any part of the structures.

Normal - which is less than desirable parameter and which can be used in case it is not possible to achieve desirable parameter.

Acceptable - which can be used in exceptional circumstances for which competent authority's approval may be sought.

Where an ideal situation exists, the target should be to achieve desirable parameter. However, if it is not possible, then it should be permissible to adopt normal parameter. But in urban areas, in a few cases as an exception, it might be necessary to allow further relaxations on acceptable standards. This has been classified under acceptable norms. It is suggested that whenever the "acceptable norms" need to be used, the Engineer will record the reasons for adopting these standards. (Whenever junctions are closely spaced and the junctions are on narrow roads and therefore cannot allow tall truck traffic or bus traffic, it can be considered to reduce the clearance at these junctions after analyzing all the relevant factors. Any vehicle requiring more than this vertical clearance can go to next ideal junction where higher clearance is available. Normally, in the pedestrian subway 2.75 meters clearance is desirable from the consideration of head loads to be carried comfortably. Most of the subways are at locations where head loads are not earned. For higher vertical clearance more effort would be required to climb up at the time of exit from the subway. It also leads to serious problem of light and ventilation. Here, reduced vertical clearance of 2.25 meters may have to be adopted.

While considering the acceptable limits, it should be carefully examined and ensured that this will not in any manner affect the proper functioning, serviceability and safety of the interchange. This should not create any possibilities for obstruction to smooth flow of traffic and causing traffic jams.

Geometric standards and other requirements can be fixed as per the recommendations in IRC:86 "Geometric Design Standards for Urban Roads in Plains" for rural areas. IRC:73 "Geometric Design Standards for Rural (Non-Urban) Highways" can also be referred.

5.11 Collection of Data and Study of Utility Services, Structures and Trees Falling in Project Area

5.11.1 *Study and mapping of utility services, structures and encroachments and trees*

The study and mapping of all the overhead and underground utility services e.g. telephone cables, water supply and sewerage pipes, gas pipes etc. or structures, encroachments falling in the project area is very important step in the planning, design, construction and maintenance of grade separators.

The knowledge of the nature, correct location, alignment, size, depth or height and the importance of the service is essential so that the requirements of shifting, relocation or its effect on design and construction are assessed and adequate steps taken to make the area encumbrance or obstruction free before the commencement of construction, so that the work is not interrupted again and again on this account causing uncontrollable delays and lots of inconvenience and discomfort to the traffic in that area.

The data about all this has to be collected from the records of the concerned organizations or agencies and by doing survey and investigations at site.

5.11.2 *Plan, program and cost estimate for removal, shifting or relocation of utility services, structures and removal of encroachments and cutting of trees*

A detailed plan of these existing services and structures should be made and then removal, shifting or relocation plan and program concerning all the departments be made separately in consultation with them.

Further requirement of utilities may also be projected in the plan.

Similarly, Plan and program for removal of encroachment be made and cost assessed.

The number of trees falling in the project area which will be required to be cut should be counted and the plan to cut or transplant them is to be prepared and necessary permissions should be taken in time. The work, many times, suffers badly on this account as the clearances required from Forest Department and Govt. of India take lot of time. The effort should, however be made to remove as minimum number of trees as possible.

As many Government organizations and other agencies are responsible for the running and maintenance of the different utility services or structures, lot of co-ordination work and efforts are required in making and implementing this shifting or relocation plan.

This also involves the expenditure incurred on this activity which is to be paid to them and provision has to be made in the cost estimate of the project. Many a times, various organizations make the estimates for this cost, as related to them, which has got to be sanctioned as per their prescribed procedure.

All this and actual shifting, removal or relocation takes very long time and constant pursuance is required. Proper provision of the time required for this work must be kept in mind while setting out the time for completion of construction.

5.11.3 *Utility planning manager/coordinator*

Considering the importance of the activity of removal, shifting/relocation of the underground and above ground utility services and structures falling in the project area, it is appropriate that one person on the project is made responsible for making the adequate studies and prepare the plan and program along with the assessment of costs involved and coordinate and monitor the progress of its implementation. He may be designated separately as Utility Planning Manager or Coordinator.

5.11.4 *Phasing out this activity*

It is also appropriate that the work of these utilities shifting etc. is got carried out separately before taking the construction of the grade separator so that the uncertainty on this account is removed and there is no adverse effect on the progress of the project as per the work program.

5.11.5 *Restrictions and limitations in planning, design and construction*

Many a times, it is not possible to remove, shift or relocate any services, encroachments or structures falling in the project area for various reasons. Such situations should be identified at the time of the above studies and a note about the same be sent to the Designer/Contractor so that its effect is adequately considered and provided for in the layout, design and methodology of construction at the initial stage itself.

Sometimes, various old, abandoned, buried or unused underground services or structures are not located from the records or site surveys and investigations and their existence is known at the time of actual construction operations of the foundations. In such cases also, its effect is to be considered by the designer and the layout, design and construction techniques are accordingly modified or revised.

5.12 Plan and Program of Acquisition of Land and Structures

It is usually not possible to plan a grade separating facility, especially in urban situations, within the land available in ROW limits of the concerned department. As such, assessment of land to be acquired and estimation of costs has to be made as per the final layout of the grade separator. The acquisition of land will also include the land required for making the diversion roads, if any.

The detailed plan of acquisition of the land and the structures has to be made and cost of acquisition worked out to be added to the cost of the project. The necessary procedure to acquire the land should be initiated well in advance so that the project is not delayed on this account.

5.13 Services Allowed to be Carried on the Elevated Superstructures

Wherever required, the structure of the bridge shall cater for traction wire supports, poles or pillars for lights, trenches or other suitable ducts for electric supply. Grade Separators are normally not expected to carry other utilities. However, in urban areas and particularly those involving crossing of railway lines (ROBs) other services and utilities such as telephone/power lines, water mains and gas line may need to be carried on the bridge structure. While planning, attention should be paid to their arrangement, location, accessibility and prevention of structural damage to the bridge.

It is recommended that water or gas mains should be supported on brackets projecting from the main structure whereby damage, if any, is limited to the bracket and does not spread to the bridge structure.

It is necessary to provide access to various utilities which are required to be maintained frequently.

5.14 Geotechnical Data

Geotechnical data is required for the design of foundation in the same manner as it is required for any bridge structure and as given in Clause **704 of** IRC:78.

One bore log shall be done at the location of each and every foundation unit. The depth of the bore shall be as per the provisions of IRC:78 for different types of foundations.

Special geo-technical investigations will be done to decide the suitability and safety of foundations in seismic conditions, wherever required.

In case of grade separators in urban situations, depths of the underground water supply lines, sewer lines & even electrical lines or gas pipe lines or structures, if any met during drilling, have also to be ascertained and shown in the borehole charts , besides the depth of water table. This will be required to decide the exact location and founding level of the foundations.

Sub-surface exploration is done to determine the suitability or otherwise of the soil surrounding the foundation and soil parameters or rock characteristics for the design of foundation, by in-situ testing or testing of samples/cores taken out of exploration.

The study and analysis of the sub-soil data will be required for deciding the type of foundations to be adopted.

The sub-surface exploration shall be planned in such a way that different types of soil upto the desired depth and their profile for the full proposed length of the flyover can be recorded. Other information such as mechanical and physical properties like grain-size distribution, sensitivity, existence of any deleterious material in soil or ground water, etc., are determined along with soil parameters and rock characteristics. The sub-surface exploration shall also throw light on porosity of rock and subsidence due to mining, ground water level, artesian condition, if any, likely sinking and driving effort, likely constructional difficulties, etc.

Field investigations of sub-surface exploration have usually three phases:

i) Reconnaissance

ii) Preliminary Explorations

iii) Detailed Explorations

Reconnaissance includes a review of available topographic and geological information, aerial photographs and data photographs and data from previous investigations and site examination.

Preliminary investigation shall include the study of existing geological information, previous site reports, geological maps, air photos, etc. and surface geological examination. For large and important structures the information may be supplemented by geophysical methods. In some cases, where no previous sub-strata data are available, exploratory geophysical investigation may need to be supplemented by resorting to a few bore-holes. These will help to narrow down the number of sites under consideration and also to locate the most desirable location for detailed sub-surface investigation like bore or drill holes, sounding probes, etc.

The scope of detailed investigation may be decided based on data obtained after preliminary investigation. Based on this, the flyover site, type of structure with span arrangement and the location and type of foundations, shall be tentatively decided. Thereafter, the scope of detailed investigation including the extent of exploration, number of bore-holes, type of soundings, type of tests, number of tests, etc, shall be decided so that adequate data considered to be necessary for the detailed design and execution are obtained.

Soil investigation for foundations shall contain a program for boring and retrieval of samples. The field work shall consist of excavation, drilling of bore-holes for the purposes of collection of undisturbed and disturbed samples, standard penetration tests, in-situ vane tests, static and dynamic cone penetration tests, other field tests, as specified by the Engineer and preparation of bore-logs. Collection and preservation for testing of disturbed and undisturbed samples from bore-holes, borrowpits, etc., as specified by the Engineer shall from a part of the above. All in-situ tests shall be supplemented by laboratory investigations. Relevant Indian Standards such as IS 1498, IS 1888, IS 1892, IS 2132, IS.2720, IS 4434 and IS 4968 and Appendix-I of IRC:78 etc., shall be followed for guidance. The soundings by dynamic method shall be carried out in bore-holes using a standard sampler as specified in IS 2131.

Detailed sub-soil exploration for the embankments in approach limits of the interchange should also be done for proper design of embankment and pavement to meet the requirements as per IRC:75 "Guidelines for Design of High Embankments" and IRC:37 "Guidelines for Design of Flexible Pavements" (Second Revision).

5.15 Climatic Data

Climatic data i.e usual annual temperature range, probable wind velocity, rainfall characteristics indicating period of rainy seasons, relative humidity and salinity or presence of harmful chemicals in the atmosphere or water, subsoil water table, susceptibility to severe storms, cyclones, etc is to be collected for deciding the various parameters of designs, durability considerations and drainage requirements.

5.16 Requirements of Aesthetics

The grade separators are very important structures and are integral part of the urban areas. As such the structural forms, lines and finishes of these structures should be pleasing and beautiful. The layouts and elevations should be planned such that these effects are created and they look sleek and fitting into the surroundings rather than looking imposing and ugly.

Bridge aesthetics is as important and necessary for grade separators as for buildings. This has, however, not been adequately recognized so far. Proper emphasis need to be given to this aspect while planning this facility.

The dimensions of various components be so proportioned that the design and appearance looks balanced and streamlined.

Pre-cast facia panels or special patterns may be used as part of superstructure to give the desired effect, if the original lines and shape fail to do so.

Landscaping of the entire area with proper and attractive plantation may add to this aspect. Various surface finishes for each element may be used to enhance the aesthetic appeal.

The concrete surfaces achieved after removal of shuttering should not be allowed to be plastered in any manner. To avoid bad surfaces use of only high quality forms should be allowed. Rubbing unevenness by carborandum stones may be done to remove oil spots of forms & make the surface fresh & new.

A large number of special architectural textures and finishes using concrete and special forms of shuttering are possible.

The surface finishes should be selected in such a manner that there is no possibility of being marred by pasting of advertisements or slogan writing.

Sometimes, painting with suitable paints may be resorted to and the same should be maintained periodically.

In moderate exposure conditions cement based paints or lime wash may be used.

In marine or other aggressive environments, special surface paints based on epoxy or polyurethane formulations can be used to help in reducing penetration of harmful chlorides or travel of moisture from surface to inside.

The painting scheme should be aesthetically appealing.

The choice should fall on simple patterns, or relief and use of colour scheme giving effect of spaciousness.

The shape and forms of Railings or Posts and Pillars etc. should be matched with the local architecture, motifs and reliefs.

Proper design of signages, illumination and road surface markings can also boost the aesthetic effects.

In case of underpasses glazed or terra-cotta tiles can be used.

5.17 Traffic Diversion and Regulation Plan

The traffic diversion and Regulation Plan during different construction stages should be visualized and tentatively decided at the planning stage for the grade separator. Many a times this not being done creates problem during construction as either the space is not available or construction methodology adopted does not permit any traffic on the possible diversions. This results in change in design or construction techniques disrupting the progress.

The diversion routes should be so planned that the disturbance to traffic on that route is minimum and for a limited period. The quality, specifications and the geometrics for the diversion roads be kept reasonably good to meet the requirement of traffic plying there and of minimum maintenance.

The construction stages of different activities can many a times be so planned that the roads i.e, service roads etc which are to be constructed as part of the project are phased and used to suit the requirements of traffic diversion.

If the diversion is planned on new land, it may require its temporary or permanent acquisition for which necessary timely action will have to be taken and cost of acquisition, will have to be added to the cost of the project.

5.18 Planning for Construction Corridor and Land Required for Construction Activities

The requirements of construction space have to be identified so that its availability could be ensured. This should consider the land and space required for creating a construction corridor for different activities at different times, in plan and elevation, without causing disturbance or obstruction to the existing traffic, for making the site office, Laboratory, storage and movement of machine and material, Batching plants, Hot mix plants and Casting Yards etc. Though this may have to be done by the construction agency but identification of the requirements and matching them with the available space and land is necessary at planning stage so that appropriate designs and construction methodology are conceived.

5.19 Environmental Issues

This is also an important aspect. All the environmental issues related to the implementation of the project should be studied and analysed so that the required clearances may be obtained in time and Enviornment Management and Mitigation Plan could be made without causing problems to the project.

Many issues involved in this may be critical on deciding the type and location of different plants, in selection of materials and method of construction to avoid air, soil and water pollution and conservation of environment and saving of energy.

5.20 Pedestrian Facilities

Suitable and adequate pedestrian facilities have to be provided at all arms of the grade separator to facilitate safe movement and passage of pedestrian traffic crossing them. If no facilities are provided they tend to cross the roads at these locations at any place risking their safety and creating chaotic conditions for the vehicular traffic leading into delays and serious accidents . The volume of pedestrian traffic and the locations where the facilities for crossing the roads are to be provided should be identified at the planning and design stage.

The type of facility, whether a signal crossing, pedestrian subway or foot over bridge, should be decided based on the functional requirements, traffic volume on the roads, traffic volume of the pedestrians, feasibility of construction and aesthetics etc. IRC:103 may be referred to for this purpose.

6 GENERAL FEATURES & GEOMETRIC STANDARDS

The objective of geometric design is to provide maximum efficiency in traffic operations and maximum safety at reasonable cost.

General Features and Geometric Standards shall be based on IRC Codes.

6.1 Carriageway Width

i) The carriageway width shall be provided as per the provisions of IRC Codes for the traffic requirements as determined by traffic census and studies.

ii) The carriageway width on the elevated structure shall be kept same as on the approaching roads on either side and the widths shall not be reduced abruptly under any circumstances.

iii) The carriageway width on the connecting one way loops or curved structures shall be not less than equal to 2- lanes.

iv) Extra widths shall be provided on curves as per the relevant IRC Codes.

v) Suitable merging lanes shall be provided in highway system, so that traffic coming down or taking off from the main roads on to the elevated structure do not cross the main traffic on the roads.

6.2 Foot Path

For safety of pedestrians, separate footpaths, where ever necessary, should be provided alongside the carriageway or urban streets. They should be provided on either side of the road and should preferably be raised above the general carriageway level. To attract full use by pedestrians, they should be properly surfaced or paved. They should be sloped adequately to drain away the rain water. Cross falls within the range of 1 in 40 to 1 in 30 are satisfactory.

The minimum width of footpath shall be 1.5 m. Those parts of the footpath immediately adjoining buildings, fences, trees and other obstructions, which will not be available for free movement of pedestrians should be disregarded while calculating widths required. Following Table provides guidelines for design of footpaths:

CAPACITY OF FOOTPATHS

Number of persons per hour		Recommended width of footpath (in meters)
All in one direction	In both directions	
1200	800	1.5
2400	1600	2.0
3600	2400	2.5
4800	3200	3.0
6000	4000	4.0

6.3 Kerb

The Kerb shall be provided on both sides of carriageway as per the details given in relevant IRC Code.

6.3.1 The kerb should be so designed that it would be safe for vertical and horizontal loads as specified under relevant clauses in IRC:6.

6.3.2 A safety kerb shall have the same outline as that of a roadway kerb except that the top width shall not be less than 600 mm.

6.3.3 This normal 225 mm high kerb may not be adequate for all grade separators in crowded areas. This may be reviewed as per the site requirements.

6.4 Railings, Parapet or Crash Barriers

6.4.1 Railings or parapets shall be provided on both sides of the bridge for the protection of traffic. Apart from its structural strength considerations shall be given primarily to the architectural features of the railing or parapet to obtain proper proportioning of its various elements to harmonise with the structure as a whole. Consideration shall also be given to avoid, as far as is possible obstruction of the view from the passing motor cars.

6.4.2 Crash barriers shall be provided for grade separators designed for high speed vehicles particularly in urban areas. Crash barrier of either steel or concrete may be provided.

6.4.3 For ROBs across railway lines, parapets shall be solid as per Railway standards.

6.4.4 Railings or parapets shall have a minimum height above the adjacent roadway or footway safety kerb surface of 1.1 metre less one half the horizontal width of the top rail or top of the parapet.

6.4.5 Where a bridge carries cycle tracks located immediately next to bridge railing or parapet, the height of the railing or parapet should be raised by 15 cm than that required otherwise.

6.4.6 Where railing is provided by top and bottom rail the clear distance from the bottom rail to the top of the kerb shall not exceed 150 mm unless the space is filled by vertical or inclined members, the clear distance between which is not more than 150 mm. The space between the bottom rail and the top rail shall be filled by means of vertical, horizontal or inclined members, the clear distance between which shall be fixed with due regard to the safety of persons and animals using the structure.

6.4.7 The details and design of Railings and Crash Barriers etc. shall conform to the requirements of IRC Standards.

6.5 Lamp Post

The height and spacing of the lamp post shall be decided to achieve the desired level of illumination on the carriageway as determined by the provisions indicated in the Chapter 15 of these guidelines

6.6 Bearings and Expansion Joints

The type of bearings and expansion joints to be provided should be carefully decided at the time of design, so that it remains functional and in place throughout the life of the structure, requiring minimum maintenance.

Improper selection of type of expansion joints and bearings results in its becoming unserviceable soon causing problems to the traffic as well as to the structure.

To improve the riding quality of road, expansion/contraction joints should be kept to a minimum.

6.7 Wearing Coat

The wearing coat shall be provided over the deck to resist traffic wear and to provide a smooth riding surface. This can be either of cement concrete or bituminous. The type of the wearing coat shall be decided at the time of design. MORT&H Specifications for Road and Bridge Works may be referred to for details.

6.8 Guardrails/Protective Measures

To protect vehicles from accidental collisions with abutments or piers, guardrails of suitable height should be provided. These should be of robust design to effectively resist uprooting and loosening of the support in the event of a collision. The ends of the guard rails should be turned away from the line of approaching traffic so as to deflect runaway vehicles which may otherwise hit the structure. It is also essential that guard rails are provided on both sides of the central piers or columns. Where raised footpath forms part of the cross-section on the abutment side, provision of guard rails is not considered necessary.

Any other form of a suitable robust protective measure may be adopted instead of the guard rails. Protective measure, so provided, shall not be an integral part of the structure.

6.9 Drainage

Effective drainage shall be ensured by providing drainage spouts connected with horizontal and vertical pipe system such that the water from the structure does not fall on the roads, does not stagnate over the roads or at entry and exit points of the grade separators and is discharged into the overall draining system devised for the project area as per the provisions in Chapter 14 of these guidelines.

6.10 Design Speed

6.10.1 Design speed is related to the function of a road. Keeping in view the type of functions expected of each class of the urban road system, the design speeds given in the following Table are recommended for adoption:

Table - Design Speeds

Classification	Design speed (km/hr)
Arterial	80
Sub-arterial	60
Collector street	50
Local street	30

6.10.2 A lower or higher value compared to that given above may be adopted depending on the presence of physical controls, roadside development and other related factors.

6.10.3 A lower design speed may be adopted in the central business area or areas with extremely heavy roadside development. On the other hand, in suburban areas, a higher value may be more appropriate.

6.10.4 For divided highways, running speeds of vehicles are in general higher and, therefore, in such cases a higher value may be adopted.

It should, however, be kept in view that sudden change in design speed along any road should be avoided. Change where necessary, should be made in stages in steps of 10 km/hr at a time.

6.11 Space Standards

6.11.1 The space standards, also commonly referred as land width or right-of-way, recommended for the various categories of urban roads are given in the Table below:

Table - Recommended Space Standards for Roads in Urban Area

Classification	Recommended Space Standards (land width) (in meters)
Arterial	50-60
Sub-arterial	30-40
Collector street	20-30
Local street	10-20

6.11.2 Standards given in the above Table are for ideal conditions. Where such space is not available, the minimum space standards shall be:

a) For separator for 4 lanes or more :
   Width of service read +5 m on either side of service road

b) For separator for 2 lanes
   Width of service road +3.8 m on either side of service road.

6.11.3 IRC:73 may be referred to for space standards in rural areas.

6.12 Camber

Camber shall be provided as per relevant IRC codes.

Camber on grade separator with high type bituminous surfacing or cement concrete surfacing should be 1.7 to 2 percent.

6.13 Super-elevation

Super-elevation shall be provided on a horizontal curvature in accordance with the relevant IRC Codes.

6.13.1 The effect of super elevation on stresses in the various members of the structure shall be taken into account in the design.

613.2 Super-elevation shall be limited to 7 percent. However, on urban sections with frequent intersections, it may be limited to 4 percent.

6.14 Gradient

The gradients in the approaching viaducts or earth embankments shall usually be limited to as per the relevant provisions of IRC codes. However, in situations where sufficient space or length is not available then the gradients may be locally increased to meet the requirement after judiciously considering the type of traffic using the facility. But in any case gradient greater than 3.5 percent should not be provided.

6.15 Vertical Curves

If there is a change of gradient on the bridge deck, suitable vertical curve shall be introduced conforming to IRC:SP:23 for small length structures.

6.16 Horizontal Curves

In general, horizontal curves should consist of a circular portion flanked by spiral transitions at both end. Design speed, super-elevation and coefficient of side friction affect the design of circular curves. Length of transition curves is determined on the basis of rate of change of centrifugal acceleration and super-elevation. For design of horizontal curves, IRC:38 may be referred to.

6.17 Widening at Curves

Wherever horizontal curves are provided in grade separators, it is necessary to widen the carriageway as per relevant codes. The structures having entry and exit ramps or loops should be provided with adequate length of acceleration/deceleration/merging lanes to ensure free and safe flow of traffic and to avoid congestion near the mouth of such ramps or loops resulting in traffic jams.

6.18 T-Junctions

Minimum radius of curvature at right angle T-junctions shall be 9 metres.

6.19 Sight Distance

6.19.1 Adequate stopping sight distance shall be provided at all points on the road in conformity with IRC standards as given in Table below:

Table - Safe Stopping Sight Distance for Various Speeds

Speed (km/hr)	Safe stopping sight distance (meter)
30	30
50	60
60	80
80	120

6.19.2 On undivided roads, intermediate sight distance which is equal to twice the stopping distance shall be provided where vehicles are permitted to cross the centerline.

6.19.3 *Headlight sight distance*

On valley curves, the design must ensure that the roadway ahead is properly illuminated during night travel by vehicle headlights for a sufficient length which enables the vehicles to brake to a stop, if necessary. This is known as the headlight sight distance and is equal to the safe stopping distance. From safety considerations, valley curves should be designed to provide for this visibility.

6.19.4 For designing valley curves, the following criteria should be followed to ensure the headlight sight distance:

- i) height of headlight above the road surface is 0.75 m
- ii) the useful beam of headlight is one degree upwards from the grade of the road; and
- iii) the height of object is nil.

6.20 Clearances at Elevated Structures

The minimum horizontal clearance shall be the clear width and the minimum vertical clearance the clear height available for the passage of traffic.

6.20.1 The minimum horizontal and vertical clearances for single and multiple lane bridges with vehicular traffic shall be given as per the provisions of IRC:5.

6.20.2 For footways and cycle tracks, a minimum vertical clearance of 2.25 m shall be provided.

6.20.3 For a bridge constructed on a horizontal curve with super elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5 multiplied by the super-elevation in m. The minimum vertical clearance shall be measured in meters from the super elevated level of the roadway. Extra horizontal clearance required for the super-elevation will be over and above the increase in width required on a curve.

6.21 Clearances at Underpass

The vertical and lateral clearances at underpass shall be provided in accordance with the stipulations in IRC: 54.

6.21.1 *Overall considerations*

6.21.1.1 Conscious effort must be made to create a sense of freedom for the drivers traveling through the underpass. As far as possible, the underpass roadway should conform to the natural lines of the highway at the approaches as regards alignment, profile and cross-section. Road profile should not dip too sharply under the structure as that will produce a considerably enhanced sense of restriction when compared with a profile that proceeds smoothly through.

6.21.1.2 To promote a feeling of openness and unrestrained lateral clearance, structures with open-end spans are recommended. Where it becomes necessary to have structures with solid abutments, these abutments should be set as far back from the roadway edge as possible. Since such structures involve higher costs these treatments may be reserved for higher categories of roads, especially with divided carriageways.

6.21.1.3 Since widening of an existing underpass at a later stage involves considerable construction and diversion problems it is recommended that the initial construction itself should take into consideration such future needs. This is particularly applicable to underpasses on important routes like National and State Highways which need to be widened from single-lane to two-lane standards after a short period as also for high density two-lane roads which are planned or earmarked for upgrading to a four-lane divided cross-section in the near future.

6.21.2 *Lateral clearance on rural roads*

6.21.2.1 *Single carriageway*

6.21.2.1.1 It is recommended that the full roadway width as at the approaches should be carried through the underpass. This implies that the minimum lateral clearance on either side must be equal to the shoulder widths. This consideration may be relaxed only in exceptional circumstances.

i)	National & State Highways	Normal 2.5 m; exceptional 2.0 m
ii)	Major District & Other District Roads	Normal 2.0 m exceptional 1.5 m
iii)	Village Roads	Normal 1.5 m; exceptional 1.0 m

6.21.2.1.2 If a footpath is provided at the underpass on a rural road, lateral clearance in the underpass portion should be the width of the footpath plus one meter.

6.21.2.2 Divided carriageways

6.21.2.2.1 Lateral clearance on left side

When an underpass is built for a divided highway, side clearance of left side shall be in accordance with the above provisions.

6.21.2.2.2 Lateral clearance on right side

In case piers or columns are provided centrally and the same are not protected by kerbed median divider, the lateral clearance shall be 2.0 m preferably and 1.5 m at the minimum. Where the median divider is kerbed, the carriageway shall be widened by 0.5 m to offset kerb shyness and the lateral clearance be kept 1.5 m (preferred) and 1.0 m at the minimum.

6.21.3 *Lateral clearance on urban roads*

6.21.3.1 Single carriageways

6.21.3.1.1 Usually roads in urban areas are bordered by kerbs on both sides. If so, these should be extended across the underpass. However, to offset the effect of kerb shyness, the carriageway in the underpass area should be widened on both sides by the side safety margin of 0.25 meter each side in the case of lower category urban roads and 0.5 meter on each side in the case of higher category urban roads.

6.21.3.1.2 If a footpath does not form part of the cross-section of the urban road, the minimum lateral clearance in addition to the side safety margin shall be increased to 0.5 meter for lower category urban roads and 1 meter for higher category roads.

6.21.3.1.3 Where a raised footpath is provided, it will not be necessary to have additional clearance beyond the width of the footpath.

6.21.3.2 Divided carriageways

6.21.3.2.1 Where the underpass serves a divided facility, the width of the carriageway should be increased on either side by the side safety margin.

6.21.3.2.2 Lateral clearance on the left hand side should conform to provisions as given earlier and right hand side lateral clearance to the face of any structure in the central median over and above the side safety margin shall be at least 1 m in the case of higher category urban roads and 0.5 m in the case of lower category urban roads. A single span structure avoiding central columns or piers should be preferred.

6.21.4 *Vertical clearance*

Vertical clearance at underpasses for road traffic shall be at least 5 meter. However, in urban areas, this should be increased to 5.50 meters. Allowance should also be made for likely overlays on the lower roads/highways.

6.22 Clearances at ROBs

6.22.1 *Vertical clearances*

For grade separators over rail lines, vertical clearance shall be kept as per the requirements of the concerned railway authorities after confirmation from them of the governing rules for the same . Minimum is 6.25 m above the rail level. This requirement usually varies with the type of services by that line and also on account of the needs of electrification of railways or dedicated freight lines etc.

6.22.2 *Horizontal clearances*

The horizontal clearances between abutments or piers shall also be determined in consultation with railway authorities. As a guidance, the horizontal clear distance between abutments for broad gauge tracks crossing at right angle are as follows:

2 lines	11.0 m
4 lines	22.0 m
6 lines	33.0 m
8 lines	44.0 m

Railway authorities, however, may like to have more than minimum distance between two lines for various reasons.

If the crossing involves one single line, provision may have to be made for second or more lines, in future. All these requirements, including future electrification system shall be finalised in consultation with railway authorities.

6.23 High Tension Lines

Where the grade separators or other elevated structures are being crossed by High Tension lines, the requirements of minimum vertical clearances below such lines should also be found out in consultation with the concerned authorities and it should be provided for in the design.

6.24 Design of Pedestrian facilities- Subways and Foot over Bridges

These shall be designed as per the relevant provisions of IRC codes. The foot over, bridges may be designed for crowded footpath loading of 500 kg/m^2 as per IRC:6. The clearances shall be as per IRC:5 or as indicated in above clauses. The access and exit to and from the subway and foot over bridge should be planned so as not to encroach in any manner upon the foot paths alongside the road carriageway and not obstruct the free flow of pedestrian traffic.

7 TYPE OF CONSTRUCTION AND STRUCTURAL FORMS

7.1 GENERAL

Depending upon the span length, space available, ease and speed of construction required, other restraints of traffic movement and regulations, limitation of movement of machinery and material and environmental issues and requirements, one of the following methods may be used for construction of superstructure:

i) Cast-in-Situ on staging

ii) Pre-cast at site or in casting yard and then erected or launched

iii) Segmental-Cast-in-situ or pre-cast

iv) Push in or incremental launching

Either girders of one span length or short segments of full deck width constitute the basic element of construction for the superstructure.

7.2 Structural Forms

The structural forms for the superstructure can be chosen from the following for arriving at the most befitting, convenient and economical solution or any other forms suiting the conditions at the site:

Solid slabs – RCC or Pre-stressed

RCC Beam-slab arrangement, where the view from underside or elevation is not very important.

Box type superstructure
Closely touching beams
Voided slab

Composite, Pre-cast Pre-stressed concrete beam or steel girders with RCC cast-in-situ deck slab, construction

Pre-cast Pre-stressed girders made continuous by using cast-in-situ cross diaphragm.

Integral structure such as rigid frame units
Extra dosed structures
Cable stayed structures

7.2.1 Structural form of superstructure should be so chosen, wherever possible, that its depth is minimum which will reduce the length of the flyover.

7.2.2 The superstructure should, as far as possible, consist of continuous spans, instead of simply supported ones. This helps in reducing its depth, improving the riding quality and durability and also improves its aesthetic appearance.

7.2.3 RCC Slab upto 10-15 m span and Pre-stressed slab upto 20 m span range can be used. Span range and economics of solid slabs can be enhanced by choosing continuous spans and increasing their depths at supports by a profiled soffit.

7.2.4 RCC Beam and Slab arrangement can be used up to 20-25 m spans. For larger spans, Pre-stressed concrete girders or steel plate girders with RCC slab can be used up to 35-40 m.

7.2.5 Continuous RCC voided slab can be provided upto 20-25 m. For span from 25 to 35 m, pre-stressed voided slabs may be used, wherever feasible and economical.

7.2.6 Simple Box girders are quite efficient forms up to 60 m as simply supported or continuous construction, but also have a wide range of application for longer spans and particularly when segmental construction is used.

7.2.7 Box girders, in general, should not be used indiscriminately in flyover structures, as they can look bulky and disproportionate for short spans.

7.2.8 Integral type structure are useful for medium or small span ranges. These are maintenance free and give better riding quality as bearings & expansion joints are not required.

7.2.9 An extra dosed bridge is more suited to longer spans ie. 50-150 m than a conventional girder bridge and be a good alternative where the site restraints require bigger span without causing any obstruction to traffic.

7.2.10 Use of cable stayed deck instead of simple box girder will result in reduced thickness of deck. This may be better solution than adopting simple box girder for the obligatory spans of flyovers, usually about 40-60 m, because the greater depth of box girder than those of other spans increases the formation level resulting in longer flyover, increased height of embankment and consequently increased cost.

7.2.11 The cable stayed structures are usually not feasible or economical for the grade separators but, sometimes can be preferred to give a better and efficient construction methodology.

Two-spans with single pylon cable-stayed, may sometimes be constructed alongside the freeway, then rotated about the pylon into its final position spanning the freeway without closing the road traffic. The second span which will act as a counter weight, may be buried under fill to make it completely invisible in the finished structure.

7.3 Methods of Construction

7.3.1 Besides usual methods of casting on staging, erecting or launching, the segmental construction is more often used to facilitate smooth flow of traffic during construction especially in urban situations and for increased speed of construction. Guidelines for segmental construction in IRC:SP:65 may be referred to.

7.3.2 Push launching is, most of the time, not feasible or even necessary. This method may be used, if suitable, in some complex situations and special conditions.

7.3.3 For Voided Slab construction, various types of void formers can be used. Spirally wound sheet metal tubes, HDPE pipes which are superior in terms of water-tightness as well as non-corrosive properties or other methods of void formation can be tried with varying degrees of success. The use of expanded polystyrene which overcomes the problem of making the void-forming material water-tight and has the further advantage of being cut to shape and size at site by a simple hand-saw, can also be used.

7.3.4 In this type of construction it has also to be kept in mind that all void formers will require secure fixing to prevent floatation during concreting. The floatation force can be substantial - even more so when combined with the vibration during the compaction of concrete. This fixing has to be planned properly. Fixing of the void former to the reinforcement cage may not be thought of as a solution, as reinforcement can float with the void formers.

7.3.5 Pre-cast pretensioned girders or steel girders with RCC slab may be used, wherever suitable.

7.4 Foundations

7.4.1 Following types of foundations are usually suitable for grade separators:

i) Open Type Foundations

ii) Pile Foundations

iii) Raft Foundations

Raft foundations

Shallow well foundations are also, sometimes, used as substitute of deep open foundation where excavation of sub-soil for the deep open foundation may not be feasible and where sufficient space is available for sinking of wells.

7.4.2 The suitability of a particular type of foundation is decided on the basis of availability and depth of suitable bearing strata, feasibility of excavation, boring or sinking efforts required for the foundations, settlement criterion and restraints because of the space, obstructing utility services or adjoining rail lines & properties etc.

7.4.3 Selection of proper type of foundation is very crucial and important as it governs the cost and time of completion of the project . Sufficient study, analysis and cost comparison should be done to decide this parameter where alternative types are possible and feasible so that both economy and speed are achieved.

7.4.4 It is desirable to use same type of foundations for any one structure to avoid dissimilar settlements which would lead to very inconvenient profile of road, poor riding quality and damage to the expansion joints.

7.4.5 In many of the city grade separators, the existing service lines create obstructions for the ideal location of a foundation. In such cases, it becomes necessary to device some special solutions which include use of eccentrically loaded foundations or odd shapes. If the obstructions are too large, it becomes necessary to put two separate foundations on either side of service lines and put a cap over the same from which the pier can start. This kind of foundation across service line is also achieved by use of piling, where possible.

7.4.6 While adopting a particular type of foundation it should be considered that it will not create any problem during construction to the traffic or the adjoining areas.

As such, it may be explored that the space is available for the heap of earth excavated in open foundation or excavation could be done by machines & excavated material be dumped in trucks & carried away immediately so that it has not to be stored in the traffic corridor which may cause constriction to traffic flow and that deep excavation, if done, will not damage adjoining property.

7.4.7 Similarly, shallow foundations are also affected by vibration of traffic. Where the foundation is to be constructed in central width of road and the traffic goes on both sides during construction or even later, the effect of vibration of the soil due to this traffic may be the additional factor to be considered for deciding the type of foundation.

7.4.8 For casting of piles, sufficient space horizontally and vertically should be available for moving the rig, for installing and erecting the rig and for operation of boring at every foundation location. Enough space should also be available for testing of piles for making platforms and for loading etc.

7.4.9 It should be explored whether driving or boring of pile will cause any adverse effect on adjoining area, structures or services.

7.4.10 Short piles should be avoided as there is lot of wastage as heavy pile caps are in any case required.

7.5 Substructure

7.5.1 The type of substructure that can be adopted will have constraints arising out of width of the flyover, foundation problems arising out of location of underground services, if any, requirements of openness etc.

7.5.2 The geometrical shape (along width of flyover) of the pier should be suitable to enable its adaptation to variable heights where the height of piers is varying as in the approach portion. Vertical shape or some other geometric shape where proportions look pleasing to the eye inspite of change in one dimension (i.e. height) may be adopted.

7.5.3 Single circular or oval piers may be suitable where least construction space is to be occupied. They look lighter and less massive.

7.5.4 Piers can be shaped and treated in many attractive ways. The vertical grooves can be introduced to accentuate the height and break the impact of width and horizontal grooves to emphasize the mass of piers and to attract attention. The mass of the abutment can be used to form sculptural treatment.

7.5.5 Elimination of pier caps by providing bearings directly over columns or piers is also useful in achieving the lightness and smooth transition between the substructure and superstructure.

7.5.6 Continuous wall type piers are usually not required in case of grade separators and can be avoided as visual transparency of the substructure is more important at these locations for better visibility of traffic and the requirements of aesthetics.

7.5.7 Row of columns should be avoided at the pier locations, as it mars the view and do not look good aesthetically.

7.5.8 Where feasible from the design considerations and where only few large diameter piles in one row have been used as foundations, the piles can be extended above the ground up to pier cap level to eliminate heavy pile caps.

7.5.9 The abutments for the viaducts can be separated from the earth fill by providing a gap topped by a slab and earth being retained by reinforced earth wall. The load bearing abutment can then be designed without earth pressure and heavy sections may not be required.

8 DESIGN

Design of grade separators shall be carried out as per relevant IRC standards.

8.1 Materials of Construction & Specifications

8.1.1 The material for the grade separators is generally concrete. But steel is also a good option, many times, for superstructures and sometimes for pier and abutments also.

8.1.2 Composite Steel construction is also in practice at suitable locations.

8.1.3 Brick or Stone Masonry is also used where appropriate.

8.1.4 Different materials may be used in different components of grade separators depending upon the appropriate use of local materials and availability of skills and expertise available, ease and economics of construction within the time and cost restraints and from the requirement of aesthetics.

8.1.5 One of the considerations in selecting the type of material is that construction should be possible without causing too much inconvenience to the existing traffic for a long time.

8.1.6 Use of High Grade or High Performance Concrete can be made to make the structure look slim and more durable.

8.1.7 Use of anti-corrosive steel or steel with anti-corrosive coating can be made in marine or corrosive environmental conditions.

8.1.8 All the materials selected for construction will conform to relevant IS Codes.

8.2 Loads

8.2.1 Loading standards shall be in accordance with IRC:6 except for the loads and part or full clauses, which are exclusively applicable to river bridges.

8.2.2 For grade separators of 2 lanes and above, live load categories as defined in IRC:6 may be adopted.

8.2.3 Bumper to Bumper Traffic

In crowded towns, vehicles have to stop at traffic signals or on account of traffic jams. In such cases vehicles may be standing bumper to bumper on grade separators. The effect of this loading should also be considered in the design.

8.2.4 Only crash barriers of steel or concrete should be provided for grade separators designed for use by high speed vehicles in urban areas just after the ends of carriageway. Where footpaths are also provided, railings should be provided at the ends. The loading and design criteria for crash barriers shall be as given in IRC:6.

8.2.5 If the founding level is below the highest water table level, then the effect of buoyancy through pore pressure may be limited to 15 percent. The structure shall be designed for dry condition of foundation and also when water table is at its highest. Appropriate safe bearing capacity shall be assessed for both conditions.

8.2.6 The foundations shall be designed to withstand the worst combination of loads and forces evaluated in accordance with the provisions of Clauses 700 and 707 of IRC: 78. The foundations shall be taken to such depths that they are sufficient from consideration of bearing capacity, settlement, stability and suitability of strata at the founding level and sufficient depth below it.

8.2.7 The relief due to passive resistance of soil below 1.5 m. of GL in front of the abutment may be considered.

8.2.8 The part of the grade separators falling in line of traffic will be designed for collision loads and impact as per IRC:78 unless these have been protected against such collision by some protective measures.

8.2.9 All the components shall be checked for different construction stages also as per the construction methodology statement.

8.3 Minimum Dimensions

8.3.1 The minimum dimensions of various members or components shall follow the provisions of relevant IRC Codes.

8.3.2 To permit inspections of the inside of the box girder the minimum overall depth of the section may be kept to about 2.25 m, if feasible.

8.4 Design for Continuity

8.4.1 The continuity of the superstructure may be achieved by providing full continuity or continuity for live load only. This is achieved by providing superstructure longitudinally continuous over intermediate supports on bearings.

8.4.2 In case of Pre-cast girders, this is achieved by casting in-situ slab and diaphragm on them after placing them in position.

8.4.3 The superstructure can be made continuous through deck slab also by two type of arrangements, one by continuous separated deck slab in which the deck slab is continued monolithically over the intermediate piers without continuing the girders. The other is tied deck continuity in which the deck slab is hinged over the pier using partly debonded dowelling.

8.4.4 The design of Continuous girder be done using the guidelines given in IRC:SP:66.

8.4.5 Rigid frames are designed for settlement of 10 mm.

8.4.6 In case of grade separator the width to span ratio is quite small, the effect of these wider decks on the dispersion of the loads should be properly considered and adequate provisions be made to ensure the structural response as per the design.

8.5 Foundations

8.5.1 The impact load from erring vehicle hitting against a pier, if no separate provisions have been made to avoid such impact, will be included in the loads and load combinations.

8.5.2 If an event is foreseen where it may become necessary to carry out excavations near the foundations of grade separators during the service life of the structure, in order to repair, replace or laying new services lines it would be preferable to take account of the extra unsupported height of about 2 m. depth for substructure and foundation designs. Service lines laid at grater depths will have to be studied separately on case by case basis.

8.6 Sub-Structure

8.6.1 The design of substructure will not require use of stream-line shapes.

8.6.2 Continuous wall type pier are not required, unless justified, for some reasons. Visual transparency of the substructure design is more important for better visibility of traffic and the requirements of aesthetics will assume primary importance.

8.7 Wearing Coat

8.7.1 Extra loads on account of the increased thickness of the wearing coat because of repeated renewals etc. should be adequately considered in the design of the superstructure.

8.8 Bearings

8.8.1 Possibility of lifting and resetting the bearings for alignment etc. should be taken into consideration while designing the bearings.

8.8.2 Location of bearings and the seismic restrainers, if provided, should be decided accurately at the time of design and the design of related components be done accordingly.

8.9 Expansion Joints

8.9.1 Efforts should be made to provide minimum number of expansion joints.

8.9.2 The expansion joints provided should be very sturdy and fixed properly to avoid their frequent repairs and dislodgement in a short time.

8.9.3 Only such type should be preferred which require minimum care and maintenance.

9 APPROACHES

9.1 The approaches on either end (excluding culvert) of any straight stilted portion shall have minimum straight length of 15 m, except where a single vertical summit curve has been provided as per the relevant clause in Chapter 6 above, having a minimum surfaced width equal to the roadway on the grade separator itself. This may be increased, where necessary, to provide minimum sight distance for the design speed.

9.2 Where horizontal curves have to be provided on the approaches beyond the straight portion on either side, the minimum radius of curvature, the super-elevation and transition length for various speeds and curve radii shall be in accordance with relevant IRC Standards.

9.3 If there is a change of gradient, suitable vertical curves shall be introduced conforming to IRC:SP:23.

9.4 Earthen Approaches

9.4.1 Earthen approaches may be provided at such places where adequate land width is available for accommodating the 1:2 slopes of the embankments and maintenance passages on both sides.

Incase there is some marginal deficiency in the land width available it may be made good by providing toe wall & pitched slopes with slightly higher slopes.

9.4.2 In such cases, it is advisable to have at least one viaduct on each side of main spans to provide for cross road traffic and one more for keeping of maintenance materials.

9.4.3 If land width is restricted, retaining walls or reinforced earth walls may be provided on both sides.

9.5 Approaches in Urban Locations

9.5.1 In urban areas sufficient width is not available and wider roads & drains are required on all sides. Earthen banks also require considerable quantity of earth which has to be brought from long distance & the cost is also more. Considerable costly land is occupied by the approaches. Solid earthen embankments also obstruct the view and do not look good. As such earthen approaches are usually not considered in such locations.

9.5.2 Viaduct spans upto a height of 5.0 m can be provided so that in the last span a vertical clearance of 3 to 3.5 m is available. This may be followed by the earthen embankments or retained embankment either by retaining walls or reinforced earth walls.

9.6 Utilization of Space below

If space below the viaduct is not used in a planned manner this will remain unclean, be misused and there would be encroachments.

9.6.1 If wide side roads are available it is possible to provide godowns or shops below, wherever feasible and required, ensuring safety of structure & proper movement of traffic.

9.6.2 If enough wide side roads are not available, the space can be used for parking of vehicles, if required and feasible from the considerations of the traffic flow.

9.6.3 The other alternative is to provide landscaping and plantations so that surroundings look clean and aesthetically beautiful.

9.7 Retaining Walls and Return Walls

9.7.1 The retaining walls should be usually simple cantilever type with correction in front slope for the deflection.

9.7.2 Counterfort retaining walls should be provided only where specifically required and economical.

9.7.3 Splayed return walls should be avoided especially in case of urban situations.

9.8 Reinforced Soil Structures

9.8.1 The reinforced soil walls can be designed as per the provisions of latest IRC codes or as per any International accepted practice.

9.8.2 Reinforced earth retaining walls constructed with soil backfill reinforced with inextensible flexible reinforcement, such as metallic strips or sheets or extensible geo-synthetic materials, such as; geo-textiles and geo-grid, are used for solid ramp portion for approaches of flyovers, grade separators and or embankment. It does not cover load bearing abutments.

9.8.3 Selected fill and filler material conforming to specifications given in relevant IRC standards are used in the reinforced soil structure as back fill behind facia panels. The material is granular and purely non-cohesive.

9.8.4 Geo-synthetic material may be woven, non-woven or knitted sheet used in geo-technical engineering and other civil engineering applications that sustain design loads at permissible strains and defined creep characteristic with maximum elongation less than the permissible limit.

9.8.5 Metallic reinforcement is in the form of strip or rod or square welded mesh/net which sustains load at strains less than or equal to the permissible value.

9.8.6 The facia panels should be cast with proper line and finish preferably in a casting yard. They can be given different treatment with patterns to suit the aesthetical requirements or giving any effect.

9.8.7 The back fill material should be properly compacted in the designed thickness of layers, as per the specifications.

9.8.8 The facia panels should be erected to give uniform surfaces and fixed to the reinforcing materials such that these are not dislodged.

9.8.9 The drainage layer of prescribed specifications should be provided as required by design and specifications and it should be ensured that it will remain functional and will not be choked because of flow of silt particles in the backfill, during the outflow of water, as it may result in the failure of embankment.

10 CONSTRUCTION METHODOLOGY, WORK PROGRAM AND QUALITY CONTROL

10.1 The detailed construction methodology statement for each major activity and overall project, should be prepared in advance of starting the construction, keeping in mind the conformity to design, traffic regulation, ease, speed and safety of construction and availability of space. This should give details of the specifications and number of different equipments, plants, materials and likely period of each activity.

10.2 A CPM or activity/progress chart should then be prepared considering all activities, some of them being independent and others being inter dependent. This should be regularly updated as per actual progress or the effect of different impediments, failures and mistakes or uncertainties. The activities falling on the critical path should be monitored properly and necessary measures should be taken timely to make up for slippages, if any.

10.3 All the activities should be integrated in the format of work program. This should indicate quantities and dates of start and completion of each activity. The resources at site in terms of men, material and machines and plants should match the requirements of the work program. Otherwise the work program should be recast with the actual resources available at site.

10.4 The work program should be so phased out that minimum disturbance is caused to traffic at any time and diversion of traffic could be planned with least inconvenience to all concerned. The work should be planned in shifts consistent with traffic constraints so that the machines and materials could be moved to site during lean traffic periods or at night.

10.5 The traffic diversion scheme should be in place before starting the actual construction work. This should be designed for the full expected traffic loads and constructed with same specifications and quality standards as the normal road. These roads should be regularly inspected and maintained properly so that the smooth flow of traffic is ensured.

10.6 Pre-cast construction techniques should be considered and used where feasible for superstructure so as to ensure faster construction and better quality and finish and to avoid the problems of lack of space during construction.

Where pre-cast construction is adopted, a suitably designed and laid out casting yard will be constructed with adequate lifting, shifting and storing arrangements and curing, preferably steam curing facilities.

10.7 The location of the casting yard shall be so chosen that enough space is available, it is near to project site and it is easy to transport the pre-cast units to the site.

10.8 The size of the casting yard will be decided according to the production capacity and to suit the requirements of these units as per the construction schedule and work program.

10.9 The quality standards will be equivalent to Q4 in conformity with IRC:SP:47.

10.10 Quality Assurance and Control Plan shall be prepared for each project on the basis of above document and the requirements at site and strictly followed during construction.

11 DESIGN OF FALSEWORK AND TEMPORARY STRUCTURES

11.1 All the formwork, staging and temporary structures, launching or erection systems should be properly designed taking into considerations the design of the structure, construction technology, site conditions including traffic regulation, safety, mobility, easy handling, line and finish required.

11.2 This should conform to the requirements of IRC:87.

11.3 All the design and detailing of the above should be checked and approved by competent authority before its use at the site.

11.4 Grade separators are important structures, mostly constructed in the vicinity or inside cities and inhabited areas, the failure of either of these during construction may cause serious problems and consequences including fatal accidents, besides disrupting the critical construction schedule.

11.5 The specially designed hydraulic operated steel moulds with surface lined with special rubber having hardness 60-70 IRHD may be used, where suitable and feasible .

11.6 Single shutters may be used for casting of pier etc. to give better finish and for faster construction.

11.7 Considering the importance of these items, one member of the project team should be earmarked as Temporary Structures Manager so that all the aspects may be given proper and adequate attention.

12 SAFETY REQUIREMENTS

There should be a Safety Plan/Manual drafted for each site considering all the safety requirements for men, machines and methods, provisions to be made, precautions to be taken and inspections and checks to be carried out.

The safety aspects may be looked after and managed by a dedicated officer earmarked exclusively for this activity on a major project.

12.1 Safety Requirements to be considered in the Design

The design should consider safe geometrics, turning radius and corresponding safe limits for speed, super-elevations and cambers, extra widths on curves and merging lanes or exit lanes etc.

Road side kerbs and railing or crash barriers properly designed and located, should be provided.

Adequate road/lane marking signs/strips should be provided.

The provision for proper lighting of the grade separators, its approaches and all the signages should be made and special lights, where required for safety or giving additional effects, may be provided.

Adequate provisions for prevention of impact/collision of vehicles should be made in the design.

12.2 Safety Requirements to be considered during Construction

Enough barricading should be done in a clean and systematic manner to enclose the work areas such that the traffic passing adjacent or in the vicinity of the site is safe and do not face any problems and the construction activities do not attract undue attention of the traffic and cause any disturbance to it. The entire construction corridor should be adequately lighted at night and enough warning/diversion/direction signs distinctly visible from distance during day and night, should be installed for safe working conditions and for facilitating the traffic.

All the equipments, machines and plants, erection, lifting and launching arrangements should be properly tested before use for performing the duties for which they would be used during construction.

All the operating staff/drivers etc. handling any activity and the corresponding machinery should be adequately briefed about the methodology and limitations of the operations so that no arbitrary discretions are used by them which may lead to unsafe conditions or failures or accidents.

It should be ensured that all the formwork, false work, temporary structures and other systems have been properly designed as per IRC:87 and approved and they conform to the site conditions.

Site office and the entire construction corridor should be properly planned and laid out for proper running of vehicles and all other activities to avoid any chances of accidents and site should be maintained neat and clean of waste materials, scraps or spilled oils, diesel or greasy or any inflammatory materials.

All measures should be taken to avoid or mitigate air, water and soil pollution so that there are no health or safety hazards.

The project site should have enough provisions of fire fighting, disaster management and medical facilities to deal with any such situations satisfactorily.

13 SIGNAGE

13.1 Adequate and proper signages should be provided at all suitable and required locations before and on the grade separated facilities to give direction and guidance to the traffic for different routes or important places well in advance and in a prominent and visible manner.

13.2 The signages may be provided as per the guidelines given in IRC:67.

13.3 Every grade separator should, preferably, be given a name, linked to its location, especially in urban situations or when located in city limits and this should be prominently displayed on the sign boards for all the directions of traffic, to facilitate the users to identify easily the exact location of passage and are alerted timely to choose the direction of destination.

13.4 The adequacy of the signage is more important for multilevel or multi arm/ loop interchanges where traffic flows uninterruptedly in different directions. There should be a bold and prominent sign board just before every entry or exit point and in addition, a repeat sign board 50 m before them.

If not guided properly by these signages, the user may have to take long detours or diversions to return to the missed entry or exit points.

13.5 It has to be ensured that all the signages are distinguishably visible at night from a reasonable distance by proper lighting.

13.6 Effectiveness of all the signages should be checked after these have been placed in their places to see if the traffic to all the destinations get timely direction and guidance and no sign or direction is missed while driving on the grade separator during day or night. If any improper size, height, placement, illumination or any obstructions to the driver's view is observed it should be corrected.

13.7 No advertisements should in any manner be allowed on these signages or on any portion or around the grade separators, as it may distract the attention of the driver.

13.8 The design, shape and size of the signages should be elegant and good looking from the considerations of usefulness and aesthetics.

14 DRAINAGE OF ROADWAY

14.1 Effective drainage shall be provided both longitudinally and transversely particularly in heavy rainfall areas. The transverse drainage shall be secured by means of suitable camber in the roadway surface. Longitudinal drainage shall be secured by means of scuppers, inlets, or other suitable means of sufficient size and numbers to drain the run-off efficiently.

14.2 Typically, water spouts are provided at the kerbs at the rate of 1 No. per 12 sqm of the surface in level portions and 1 No. per 15 sqm of the surface area on gradients. Water spouts are connected to runner pipe of suitable diameter (minimum 100 mm) on either side of roadway and taken down by downtake pipes at pier & abutment locations.

14.3 Drainage fixtures and downspouts, if provided, shall be of rigid, corrosion resistant material not less than 100 mm as the least dimension and shall be provided with suitable cleanout fixtures.

14.4 The arrangement of floor drains shall be such as to prevent the splashing discharge of drainage water against any portion of the structure. Overhanging portions of concrete floors shall be provided with drip moulds.

14.5 Catch water drains are necessary at the end of viaduct portion so that water coming from span does not over saturate and affect the earthen embankment. Similar catch water drains should be at the end of gradient so that water coming from flyover is properly let out to nearest drain.

14.6 An integrated drainage plan for the water coming from the deck of structures, local catchment area of the project and all other sources should be prepared so that no water falls on any surface of the structures, or remain standing or flowing over the level roads. All the water is collected through sumps and finally discharged into the local drainage systems i.e., storm water pipes etc. either by gravity through connecting drains or by pumping into the existing outgoing drains.

14.7 The rainwater from the decks of the structures usually does not flow transversely but flows on the high gradient slopes of the roads or approaches and is collected in the valley curve portion. As such attention is to be paid to get this large quantity of water drained out fast without accumulating there causing problems for traffic flow resulting in traffic jams. The draining out systems should be designed with greater margins so as to avoid this problem, at least for grade separators inside the cities or inhabited areas.

15 ILLUMINATION

15.1 Standards of Illumination

Recommendations relating to lighting of public highways, including grade separators, are contained in CIE. (Commission International de L'Eclairage) recommendations as detailed below:

15.1.1 *Glossary of terms*

Candela (cd): The unit of luminous intensity.

Candlepower (cp): Luminous intensity expressed in Candelas. It is not an indication of total light output.

Co-efficient of utilization (cu): The ratio of the luminous flux (lumens) from the lantern received on the surface of the roadway to the lumens emitted by the lantern lamp alone.

Lantern: A complete unit consisting of lamp, choke, capacitor together with the parts designed to distribute the light, to position and protect the lamp and to connect the lamp to power supply.

Lighting unit: Assembly of light pole & lantern

Lumen : The unit of luminous flux

Luminance (photometric brightness) - Brightness of any diffusively reflecting surface illuminated at a density of luminous flux.

Lux (1x) - SI unit of illumination on a surface of one square meter in area from a uniform source of candela intensity or equal to one lumen per square meter.

Luminous flux - Total light radiated by a light source as evaluated photometrically.

Maintenance factor - Ratio of average illumination on the working area, given by a new installation to that of an installation with decreased effectiveness due to dust, ageing of lamp, etc.

15.1.2 *Design requirements and brief specifications*

15.1.2.1 The quality of lighting shall comply with the CIE Recommendation No.12, The illumination system shall be suitably designed for luminance level, overall uniformity ratio and length wise uniformity ratio.

Average maintained luminance		=	luminance - 2.5 cd/m^2
		=	luminance, E_{av} = 35-50 lux/m^2
Uniformity ratio =	$\frac{E_{min}}{E_{av}}$	=	longitudinal 0.7
		=	transverse 0.35

Or as required for local conditions

Maintenance factor	=	0.75
Class of pavement (CIE Recommendations)	=	R3 or R4

15.1.2.2 The luminance levels are the maintained-in-service values after taking into account light loss factors.

15.1.2.3 Continuous lighting shall only be permitted at all locations except for loops, merging zones, pedestrian crossing where safety lighting shall be used. The lighting unit shall be such that, under practical conditions, the luminance pattern actually obtained from the installation shall be uniform in the longitudinal and lateral axis of the road. The units that produce a ladder or zebra effect, i.e., bright and dark spots will not be accepted.

15.1.2.4 High Pressure Sodium or some standard light source may be used. The high pressure sodium lamps shall have the following minimum lighting output after 200 burning hours :

150 W	14,500	1 m
250 W	25,500	1 m
400 W	48,000	1 m

15.1.2.5 The lanterns shall have protection degree, minimum LP 55, according to LE C 144.

15.1.2.6 For each designed lighting installation, calculations shall be provided for luminance distribution, longitudinal and overall uniformity on the surface. All photometric calculations shall be made as per CIE recommendations.

The following data/parameters will be required or making these calculations:

i) The geometric characteristics of the road surface
   - mounting light,
   - road width,
   - space between lanterns,
   - type of arrangement.

ii) The photometric characteristics of the road surface
   - R1- Asphalt surface with at least 15 percent of artificial brightener
   - R2 - Coarse asphaltic concrete

     Asphalt surfaces with 10-15 percent artificial brightener.

     R3 - Asphaltic concrete (cold asphalt)

     R4 - Mastic asphalt
   - Smooth textured road surfaces (As defined by I.E.C.)

iii) The photometric characteristics of the lanterns

     i.e. the spectral distribution table of luminous intensities for the type of lamp employed.

iv) The luminance (and illuminance) field of calculation

v) The position of the observer

vi) Maintenance factor

15.1.2.7 These are calculated from the following information supplied by the manufacturers.

i) Spectral distribution curves (polar curves) for the proposed lighting unit.

ii) Iso-Cande!a diagrams of the lighting unit

iii) Iso-lux curves for the recommended spacing

iv) Iso-luminance diagrams of the lighting unit

v) Co-efficient of utilization of the lighting unit

15.1.3 *Types of illumination systems*

i) Normal street light

ii) Single/double bracket street light poles

iii) High mast lights

iv) Combination of normal street light poles either with single luminaries or twin luminaries and a number of light mast lights with multi-uminaries

15.1.3.1 Illumination of ROBs and earth filled approaches

The first two systems are usually sufficient for railway over bridges, on the stilted flyovers as well as on its earth filled approaches, rural or semi-urban structures and generally for two lane elevated carriageways. Double bracket 250 W luminaries are used preferably in the Central Verge. Alternatively, single bracket lights in one side of the road/flyover may be provided with about 8 to 9 m high poles. The height of the pole and its distance including the angle and capacity of the luminaries should be so designed to achieve an average illumination level of 30 lux with maintenance factor of 0.7 and average illumination factor of 0.4.

15.1.3.2 Illumination of a rural or semi-urban grade separator

These structures, generally being two lane, can be illuminated with the first two systems.

Only at the junction of the grade separators with 4 or more lanes stilts carriageways, where lighting on the top level will create heavy shades/shadows or the lower level roads, question of providing high mast lighting at the corners as per the system given later can be considered. Perhaps only four high masts particularly in the four corners of the slip roads may achieve the required level of illumination along with normal street light poles.

15.1.3.3 Illumination for urban grade separators

In this case, the elevated road being at least of 4 lane carriageway i.e. 2 lanes in each directions, the width of the elevated road causes shadows/shades underneath such carriageways. Further, presence of trumpets and clover leaves complicates the problem. In such cases, use of high mast lights (lights with the height of poles/masts more than 10 m and maximum upto 50 m) with required no. of luminaries to be attached on the head frame are essential. The total illumination system which will comprise of a combination of normal street light poles either with single luminaries or twin luminaries and a number of a light mast lights with multi-luminaries, should be so designed to achieve an illumination level, as given above, throughout the intersection.

15.1.3.4 Arrangement for beautification of the structure

Street light structures and luminaries are often used as an instrument for beautification of the road. It is however essential, considering the different intensities of head lights of various types of vehicles in Indian roads that due attention is paid to the illumination level on the carriage way.

15.1.3.5 It is desirable to have the lighting circuit distributed in three phases, so that even if one phase goes off, a part of the lights will be in operation. Electro-mechanical timers be provided for auto-switching on and off to avoid separate manpower requirement particularly in out of the way places.

15.2 Design and Specifications of Masts

15.2.1 High masts are to be generally designed as per the guidelines given in the Technical Report No. 7 of the Association of Public Lighting Engineers, U.K. as published in 1976. The masts should be designed for withstanding a 3 second gust of a specified wind speed (Say 50 meters per second or as can be assessed from IS 875 (Part 3) -I978) for a defined ground roughness category and specified class of structure.

15.2.2 The luminaries should be integrated type i.e. single housing should accommodate the luminaries (Flood lights) and its control unit.

15.2.3 The mast shall be manufactured from high tensile steel plate, cut and folded to form continuously tapered polygonal profile. The 30 m mast shall comprise of three suitable lengths before installation. The number of horizontal press fits should in any case not exceed three. The three sections should be fitted together on site in a manner that does not require any BSEN 10025 welding. Rather, one unit should be fitted telescopically into another with sufficient anchorage length to ensure that no transverse welding of the joints are needed. Transverse welds will not be allowed in the body of the mast.

15.2.4 Steel conforming to BS : 1461(1999) or equivalent IS shall be used for the construction of the mast and after all welding processes are completed, the mast shall be hot dip galvanized to BS : 1461 (1999) or equivalent ISS.

15.2.5 The base flange shall be manufactured from steel plate free from laminations. The base shaft should penetrate the full depth of base plate and should be welded both above and below using a semi automatic MIC shielded arc process. Gussets shall be located between each hole position, for additional strength.

15.2.6 Base compartment shall consist of an access opening to the base compartment should be an aperture of dimensions 240 mm x 740 mm approximately and should be reinforced to maintain the strength of the mast. Computer calculations for stresses and deflections should take into account the reinforcement of the access opening.

15.2.7 The base of the left out door should be located on a substantial leg and secured at the top by means of recessed/socket head screw.

15.2.8 Base board shall be provided for mounting electrical and control equipment and should have minimum dimension of 315 x 395 mm.

15.2.9 Earthling Terminal shall have M12 hexagonal head bolt complete with saddle bracket located on the left of the access opening of the mast shall be used as earthling terminal.

15.2.10 The head frame, designed to be a capping unit of the mast, shall be welded steel construction and hot dip galvanished after assembly.

15.2.11 The lantern carriage shall be of the sheet steel construction and shall be hot dip galvanished after assembly. The carriage shall be in the form of a ring split on one diameter, enabling it to be assembled or removed from the shaft after erection.

15.2.12 The outside base of the ring shall be provided with spigots or supporting brackets welded to it, depending on the form of lighting required. 4 sets of double rollers on the inside of the ring which engage with the slides on the mast head shall be provided, to ensure that when the carriage is fully home there is no movement between the carriage and the head frame. Additionally, a PVC buffer section shall be provided for protection of the mast during lowering the carriage.

15.2.13 A cast aluminum junction box located on the lantern carriage and housing connections to the lantern shall be provided. The junction box shall also have provision for connection of the flexible mast electric cable. The junction box shall be of casketed construction to ensure complete protection against weather.

15.2.14 A wiring duct shall be provided which should carry electrical wiring from the junction box to the lanterns.

15.2.15 Each mast shall be provided with flexible multi - core cable. The conductor core shall be insulated with Ethylene propylene rubber and the complete cable core shall be sheathed in heavy duty polychloroprene.

15.2.16 An electrical disconnect shall be provided at the base of the mast comprising a socket with coupling ring and threaded plug including one set of 3 MCB SP and 1 MCB for NL for complete disconnection of electric supply. It shall be possible that for lowering the lantern carriage, the electrical cable is disconnected at the base, so that it is free to travel within the mast.

15.2.17 The double drum winch shall have a safe working load of 330 kg for each drum at operating speed of 380 rpm. The winch shall be capable of handling total loads of upto 660 kg.

15.2.18 Two cast iron worm reduction gear boxes shall be provided, which shall be filled with lubricant in the factory and should require no further attention at site. The gears shall have a reduction ratio of 50 : l and provision shall be made for both manual as well as electric power drive.

15.2.19 The drum shall be fabricated from steel. To ensure correct rope stacking, a minimum one full layer of rope shall remain on the drums after the lantern carriage has been lowered to its lowest position. The double drum which shall use an arrangement of two independent ropes and each rope shall have one end attached to the lantern carriage and the other and clamped to the winch drum.

15.2.20 The control arrangement shall allow two sets of gears and their drums to be rotated simultaneously from a single driven shaft for normal operating duty of raising and lowering. Additionally, a separate manual function shall permit the lower drum to be rotated independently for leveling the lantern carriage. Additional safety features shall include disc brake on both gear shafts and automatic gravity latches which separately lock each drive shaft. Each winch shall be numbered and separately tested.

15.2.21 All wire ropes shall be of stainless steel and having a tensile strength, of 165 kg/mm^2. The rope shall have a construction of 7/19 on a PVC core to combine corrosion resistance with flexibility. The rope of 6 mm diameter shall provide a 330 kg of safe working load at a safety factor of over five. The central core of wire rope shall also be stainless steel. No intermediate joints in the wire ropes are acceptable.

15.2.22 The external electric driven power tool shall be single speed (1.2 meters per minute) single phase, hand operated motor. The power too shall be completed with very robust remote control switch such that the tool can be operated from safe distance of five meters.

15.2.23 The maintenance cage shall be designed to accommodate two men together with any maintenance equipment and shall comply where relevant, with the constructional (lifting operations) regulations, 1961. The cradle shall be capable of raising or lowering by the mast winch and wire ropes. The entire maintenance cradle shall be hot dipped galvanized after fabrication. A maintenance manual shall be finalized during installation of the mast and the floodlights to ensure regular inspection and proper maintenance.

15.3 Energy Conservation

There is need to conserve electrical energy consumption, particularly during late night hours or early morning hours when the traffic density is rather low. Special ballasts for HPSV lamps have now been developed, which reduce the lighting levels and electrical energy consumption after specified hours on each day. Use of such ballasts should be preferred in future installations.

15.4 Lighting Pollution

High mast lighting may cause lighting pollution, particularly in urban areas, where high rise apartments or Airports are in the vicinity. A fiber glass canopy suitably provided over the lantern carriage will prevent spilling of light in azimuth thus, reducing light pollution in the sky.

15.5 Example

A typical example of design for Illumination is given below:

Class of pavement according to the CIE	R3
Maintenance factor	0.75
Voltage drop for the last pole of the circuit	Maximum, 3 percent
Supply system	3 x 380/220 V : 50 Hz

Electric lighting poles of 10 m height with the top cantilevering out by 2 m are provided at 37 m centers on alternate sides to carry 400 W high pressure sodium vapor lamps. The poles are of 200 x 200 x 10 mm rolled hollow steel, hot dip galvanized, and designed to withstand wind speeds of 160 km/h. The main distribution board for receiving the three phase power supplies from the public utility system and distributing the same for the lighting is provided at an appropriate place. The distribution of power supply is through insulated PVC armored cables of cross- section ranging from 16 mm square to 2.5 mm square. An automatic on/off switching system based on the density of natural light has been provided. This is a solid state control device, incorporating a photoelectric cell for automatically switching the lighting system based on the intensity of daylight. The device automatically switches on/off at preset lighting intensity. The unit is adjustable from 0.2 Lux to 8 Lux. Apart from saving in power, the system also enables reduced maintenance and replacement requirements. The cables are carried through the length of the bridge for distribution to the light poles through a 150 mm dia PVC pipe embedded in foot path slab.

16 CONSTRUCTION PROBLEMS AND PROCEDURES

16.1 Introduction

The problems faced during implementation of flyovers and other elevated structures are of different nature and are required to be tackled at different stages of inception, design and construction.

16.1.1 The problem faced during construction are related to lack of attention to various requirements of data collection, planning process and the investigations required.

16.1.2 The problems faced are mainly on account of:

i) Non-availability of encumbrance free project site and construction corridor

ii) Disruption of work because of encroachments, trees, land or structures to be acquired or obstructions due to on or under ground utility services

iii) Lack of proper data and understanding of procedures for removal of the encroachments, acquisition and removal, shifting or relocation of utility services

iv) Lack of coordination between the various organizations and agencies involved and responsible for the above

v) Lack of any realistic work program based on resources and restraints, or when the critical activities are not identified and timely action not taken to perform or complete them.

vi) No proper phasing out of different activities keeping in mind various requirements and limitations at site.

vii) Lack of proper sub-soil investigations resulting in inappropriate type of founding systems etc.

viii) Selection of improper or inappropriate construction technology

ix) Improper traffic data making traffic diversion and regulation difficult at the time of construction

x) Restricted working hours for some important activities which involve movement of material and machinery

xi) Non-availability of land for casting yard, storage of materials, setting up of the batching plants etc. in nearby locality making handling more difficult

xii) Strict regulations for environmental issues imposing too many restrictions and limitations for procedures and compliances.

xiii) Poor quality control and assurance measures or practices which may result in redoing many activities

xiv) Insufficient resources as per the work program

xv) Insufficient safety measures and improper compliances of various regulations which lead to accidents during construction causing disruption of work

16.1.3 These problems can be completely avoided or mitigated, if the planning is done with full care and concern, addressing all the issues as given in Chapter 5-Planning.

16.2 Pre-Construction Requirements

16.2.1 Project office should be established with proper lay out and space with demarcated places for offices, meeting rooms, Test laboratories, labour sheds, canteen, batching plants, hot mix plants, storage of materials pathways, roads etc. in such a manner that there is no congestion, obstruction or disturbance to any activities because of the others.

The entire complex need to be kept neat and tidy without any stagnant water or waste materials and so as not to create any air, water, soil or noise pollution.

16.2.2 Construction methods should be planned adequately to cater for suitable regulation of traffic movement and traffic diversion and avoidance of public inconvenience to a minimum.

16.2.3 Movement of machines and materials should be properly planned in advance for smooth execution of work.

16.2.4 Planning for adequate availability of land either close to construction site or away from it, needs to be adequately catered for installing concrete batching plants, stone crushers, WMM Plants, HMM plant etc. as required for execution of the project.

16.3 Environmental Measures

16.3.1 All precautions should be taken for safeguarding the environment during the course of the construction of the works. All laws, rules and regulations in force governing pollution and environmental protection that are applicable in the area should be followed where the works are situated.

16.3.2 Borrow-pits should be dug in conformity with MORT&H Specifications from approved sources with preference given to materials becoming available from nearby roadway excavation source. There shall be full compliance of environmental requirements in respect of excavation and borrow areas as stipulated by Ministry of Environment and Forests and local bodies.

16.3.3 Materials from quarries should be obtained only after the consent of the Forest Department or other concerned authorities is obtained. The quarry operations should be undertaken within the purview of the rules and regulations in force.

16.3.4 Bituminous Hot-Mix Plants and Concrete Batching Plants should be located sufficiently away from habitation, agricultural operations or industrial establishments. Precaution ought to be taken to reduce the levels of noise, vibration, dust and emissions from the plant. Any materials, which are hazardous to the health of persons, animals or vegetation, should not be used. Protective clothing and safety appliances to the workers needs to be provided.

16.3.5 All reasonable steps need be taken to minimise dust nuisance during the construction of the works. All noise pollution activities should be controlled adequately. All existing highways and roads used by vehicles for suppliers of materials or plant, and similarly any new roads which are part of the works and which are being used by traffic, should be kept clean and clear of all dust/mud. Other extraneous materials and debris etc. from the works spreading on these highways ought to be immediately cleared during execution of works. Clearance has to be effected immediately by manual sweeping or mechanical methods . All dust, mud and other debris needs to be removed entirely from the road surface regularly.

16.3.6 Any structural damage caused to the existing roads by the construction equipment should be made good.

16.4 Traffic Arrangement During Construction

16.4.1 The work should be carried out on the highway in a manner creating least interference to the flow of traffic while consistent with the satisfactory execution of the same. For all works involving improvements at the existing location of grade separator, it is necessary to provide and maintain, during execution of the work, a passage for traffic either along a part of the existing carriageway, or along a temporary diversion constructed close by. Traffic arrangements scheme needs be worked out and implemented as per prevalent traffic norms during construction.

16.4.2 *Passage of traffic along the existing carriageway during construction of grade separator*

Widening/strengthening of existing location of grade separator along carriageway, where part width is proposed to be used for passage of traffic, should be done. Treated shoulders should be provided on the side on which work is not in progress. The treatment to the shoulder should consist of providing at least 150 mm thick granular base course covered with bituminous surface dressing in a width of at least 1.5 m and the surface should be maintained throughout the period during which traffic uses the same.

16.4.2.1 The continuous length, in which such work shall be carried out, would be limited normally to 500 m at a place.

16.4.2.2 In case of widening of existing two-lane to four-lane to accommodate grade separator, the additional two lanes would be constructed first and the traffic diverted to it prior to the required construction of grade separator.

16.4.3 *Passage of traffic along a temporary diversion*

16.4.3.1 In stretches where it is not possible to pass the traffic on part width of the carriageway, a temporary diversion should be constructed with 7 m carriageway and 2.5 m earthen shoulders on each side (total width of roadway 12 m) with the following provision for road crust in the 7 m widths:

i) 200 mm (compacted) granular sub-base;

ii) 225 mm (compacted) granular base-course: and

iii) Premix carpet with Seal Coat/Mix seal surfacing.

16.4.3.2 The alignment and longitudinal section of diversion including junctions and temporary cross drainage provision should be properly designed and implemented.

16.4.4 *Traffic safety and control*

16.4.4.1 All necessary measures should be undertaken for ensuring satisfactory flow of traffic during construction and provide, erect and maintain such barricades, including signs, markings, flags, lights and flagmen as may be required for the information and protection of traffic approaching or passing through the section of the highway under improvement. Before taking up any construction, an agreed phased program for the diversion of traffic on the highway shall be drawn up.

16.4.4.2 The barricades erected on either side of the carriageway/portion of the carriageway closed to traffic, should be of strong design to resist violation and painted with alternate black and white stripes. Red lanterns or warning lights of similar type should be mounted on the barricades at night and kept lit throughout from sunset to sunrise.

16.4.4.3 At the points where traffic is to deviate from its normal path (whether on temporary diversion or part width of the carriageway) the channel for traffic shall be clearly marked with the aid of pavement markings, painted drums or a similar device. At night, the passage shall be delineated with lanterns or other suitable light source.

16.4.4.4 One-way traffic operation should be established whenever the traffic is to be passed over part of the carriageway inadequate for two-lane traffic. This should be done with the help of temporary traffic signals or flagmen kept positioned on opposite sides during all hours. For regulation of traffic, the flagmen should be equipped with red and green flags and lanterns/lights.

16.4.4.5 On both sides, suitable regulatory/warning signs should be installed for the guidance of road users. On each approach, at least two signs shall be put up, one close to the point where transition of carriageway begins and the other 120 m away. The signs shall be of approved design and of reflector type as required.

16.4.4.6 Signs, lights, barriers and other traffic control devices, as well as the riding surface of diversions should be maintained in a satisfactory condition till such time they are required. Temporary travelled way should be kept free of dust by frequent applications of water as necessary.

16.5 Shifting of Services

16.5.1 All the underground and overhead services and structures and encroachments have to be removed or shifted, and traffic diversions have to be managed before the construction can start. Usually this takes unduly long time. Because of the uncertainty of the time required for this activity, work program cannot be implemented and there are long delays and time overrun. This leads to idling of labour and machines and increase in overhead expenditures and consequently there is cost over run as well.

16.5.2 The problem of underground utility services gets further aggravated because of lack of knowledge about their existence underneath or their exact alignment at the time of preparation of project report or finalisation of designs. As such, these are located at the time of excavation of foundation or driving of piles etc. This creates lot of problems because the work has to be stopped and process of removing or shifting started causing delays in the construction work indefinitely. In some cases where the removal or shifting of the service is not feasible, then the design has to be modified or changed completely to avoid the obstruction.

16.5.3 As the utility services are related to various departments, their removal or shifting involves coordination between them. In most of the cases, this work is carried out without any sense of urgency or concern and without caring for the work program. The various agencies work at their own convenience and as such work gets done in piecemeal and without any planned and phased sequence, upsetting all time and cost schedules, besides causing continued inconvenience to the public.

16.5.4 A dedicated Utility Manager or Coordinator should be assigned with the job of handling this activity .

16.5.5 The construction of the flyovers and elevated structures needs to be planned and executed very meticulously. It is desirable that the required investigations about the location of the underground services, subsoil conditions and other issues, sorted out before finalising the scheme.

The various pre-requisites are as follows:

a) Detailed studies should be made to decide the location and alignment of the underground services, live or defunct, and other/underneath structures, from the records available, exploring all the possibilities depending upon the cultural, geographical and historical importance of the location.

b) Detailed exploratory and subsoil investigations should be done along the alignment and at the proposed locations of the foundations.

c) Shifting and removal of the services and encroachments should be planned in advance and work plan should match with the availability of right of way.

d) Availability of space at site should be kept in view while planning and designing, so that problems are not faced at the time of actual construction. Lack of working space should be adequately considered for type of design and suitability for construction within the space available.

e) The alignment, location of pier and type of foundation and its depth should be carefully decided to suit the local conditions.

f) The construction methodology should be so chosen, that it is suitable at site, is time saving and cost effective.

g) Precast construction techniques should be considered and used where feasible for superstructure so as to ensure faster construction and better quality and finish and to avoid the problems of lack of space during construction.

h) The work program should be so phased out that minimum disturbance is caused to traffic at any time and diversion of traffic could be planned with least inconvenience to all concerned.

i) The work should be planned in shifts consistent with traffic constraints so that the machines and materials could be moved to site during lean traffic periods or at night.

j) Enough barricading should be done in a clean and systematic manner to enclose the work areas such that the construction activities do not attract undue attention of the traffic and cause any disturbance to it.

k) Adequate safety measures should be adopted as per the construction safety manuals or various regulations or as per the requirements at site.

17 INSPECTION AND MAINTENANCE

17.1 Introduction

17.1.1 The grade separators are very important structures and need to be kept in traffic worthy condition all the time. It is necessary that all these structures are regularly inspected during construction to ensure quality during and after construction as per a pre-determined program or for specific requirements and maintained or repaired or rehabilitated at the earliest as may be demanded as per the result of these inspections.

17.1.2 The inspection after construction and maintenance of grade separators can be done conforming to the provisions of IRC:SP:35 except for its clauses and provisions which are applicable to river bridges only.

17.1.3 There are severe threats to durability and longevity of structures, especially for urban grade separators because of their location, carrying traffic much beyond the designed volume in over populated cities ,increasing industrialization giving rise to increased level of pollution and toxicity in the environment and because of use of new type of materials, structural systems and faster construction techniques, which have not been tested in the past, creating lot of uncertainties about the long term behaviour of materials and systems .

As such, a suitable inspection and maintenance program need to be implemented to take timely remedial measures and rehabilitate the structure before the situation worsens, if these structures can serve for their designed life. A suitable mobile inspection unit may be used to facilitate the inspection, if required to suit the above program.

17.1.4 All the activities during construction are required to be inspected thoroughly.

After construction, the parts which require special and frequent attention are bearings, expansion/contraction joints, drainage arrangements, etc.,

17.1.5 The design of a grade separator, therefore, should provide for -

Noticeable visual indications of impending failure.

Facilities for detailed inspection, repair and rehabilitation works.

17.2 Access for Inspection

17.2.1 To facilitate inspection, suitable facilities should exist for the personnel to access the parts or activities which are to be inspected during construction or after construction or for maintenance. Mobile inspection units can be deployed wherever feasible, or local arrangements suiting the requirements of inspections can be made.

17.2.2 A suitable access system provided at the time of construction can be more helpful and practical arrangement for subsequent inspections after construction and for carrying out regular maintenance and foreseeable repairs as easily as possible. It ensures full safety of staff and causes least possible interruption to the traffic, both above the flyover as well as the carriageway below it. The inspectors should be able to reach vulnerable points as easily as possible, inspect and maintain or repair them.

17.2.2.1 Inspection platform around pier and abutment with railings and access ladders should be provided for this purpose.

17.2.2.2 An opening in the diaphragms of box girders is suitable for inspection inside the box. The size of opening should be such that men and equipment can be taken inside. Sometimes manholes are provided in the bottom slab of the box.

17.2.2.3 For long flyovers and continuous bridges, access vestibule at one end may be ideally suitable. Such a vestibule provides easy access to the inside of the box girder and even heavy equipment can be taken through this vestibule. This area can be used for housing bridge monitoring equipment. This also helps in relieving the earth pressure surcharge on abutment.

17.2.2.4 Expansion joints provided at the end of girders on the top of pier and abutment need regular inspection. A suitable space between the end faces of main beams or an inspection gallery around pier facilitates this inspection.

17.2.2.5 Leakages from the drainage spouts or down take pipes should be noticed and remedial measures taken immediately. Inspection of drainage spouts can be done from footpaths.

17.2.2.6 Deflection/Camber monitoring is an important aspect of inspection. Suitable platforms constructed to facilitate taking readings will be helpful in monitoring deflection/ camber of the girders.

Some 100 mm square patches made even at regular longitudinal and transverse intervals (as reference locations on the carriageway) could be used for periodic collection of profile data. Such periodic deflection/profile monitoring of the superstructure enables taking appropriate corrective measures including resurfacing.

17.2.2.7 Where footpaths have not been provided, a walkway or gangway is helpful for inspection and maintenance personnel.

17.3 Drainage System

The drainage system should be carefully inspected during rainy season to ensure that its functioning remains effective and serviceable during the critical conditions. Any stagnation or collection of water over the deck, carriageway, valley curves or in surrounding lanes or areas should be noticed and appropriate remedial measures be implemented.

17.4 Illumination System

The entire illumination system for the grade separator, signages and surrounding area need to be inspected frequently to check its functioning and effectiveness. The frequency of its failure at any point should be analysed and proper remedial measures be taken to ensure that sufficient illumination is available at all locations during night or darkness.

17.5 Erection, Launching and Lifting Arrangements

17.5.1 The lifting of girder for replacement of bearings should be inspected to ensure that the lifting is being done at the designated design points only as may be marked on the drawings and it is being carried out as per the procedure laid out.

17.5.2 All the systems and machines used for construction, for erection, launching or lifting should be thoroughly inspected to check that these are as per required and prescribed specifications and are in good working conditions and are not being overloaded during their use.

17.5.3 These should be inspected and test loaded after some repeated use, to check that there are no distress, deformities and malfunctioning in them to make them unsafe for further use.

17.6 Construction Machines, Plants and Equipments

17.6.1 All the construction plants and machinery and equipment should be regularly inspected at designated frequency or as required to check their efficiency and proper functioning and to take measures for their servicing or repair in time so that they do not remain idle at the site.

17.6.2 It should be seen that these have been calibrated at the prescribed frequency or in case of any doubt.

17.7 Maintenance Manual

A maintenance manual should be prepared for all the grade separators where there are some special or specific maintenance requirements because of the design philosophy or site requirements etc. The maintenance of the structure should accordingly be ensured.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)