PUBLIC WORKS DEPARTMENT

Government of Delhi

Urban Roads

Manual

(Second Edition)

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CONTENTS

PREFACE

Urban roads are part of urban infrastructure. These roads are required for both intra-city and intercity movement and render much higher level of service compared to Regional Roads, State Highways and National Highways. Importance of Urban roads is increasing on account of the fact that urban areas are increasing in their size and number. The planning, development and maintenance of urban roads offer challenge to Engineers. Quality of life in urban area depends on efficient and effective urban Road system, of course, with the support of other infrastructural services such as water supply, sewerage, drainage, electricity, telephones etc. in order to, perform social economical & cultural activities.' Urban transportation network is required to facilitate movement of people and goods and therefore efficient network is necessary for their efficient movement. Urban roads being most importantmode of transportation, these are required to establish a reliable, efficient and attractivetransportation system for vehicles and individuals.

IRC documentation by and large deals with National highways state highways, major district roads, other district roads, village roads etc. Most of the documentation by Indian Roads Congress arefor inter-city linkage not for intra-city linkages. Most of the literature developed by Indian road Congress is for inter-city or regional roads which are under the preview of Ministry of Surface Transport whereas 'Urban roads are under the preview Ministry of urban Development. Central PWD being under this Ministry has, therefore, taken initiative to prepare the Urban Roads Manual Though this manual is prepared for those engineers of Central P.W.D who are working in PWD, Government of NCT Delhi, but it is hoped that it will be found equally useful by the road engineers of State PWD and other similar organisations. This manual is a practical guide for planning, construction and maintenance of roads. It is based mostly on IRC publications and wherever required, publications of Delhi Development Authority (DDA), Municipal Corporration of Delhi (MCD) etc., have been used. There is limitation of space in urban roads. Therefore, requirement of geometry to ensure proper safety is a difficult task. These roads are to be designed to accommodate peak hour traffic as also lean traffic. Other important features of urban roadare lighting,

proper maintenance, traffic requirements.The performance demand from urban roadschangein short periods. Today's road in out-skirts ofthe city after some time have to caterforsemi-urban conditions and in future to fully urban conditions. Besides, urban roads are required to accommodate many other services for which requirements vary with the passage of time.

PWDs, Municipal Bodies and Urban Development Authorities are generally inchargeof planning, construction and maintenance of urban roads.

Adequate knowledge about different aspects of urban roads in comprehensive manner are important for Engineers in charge of urban roads. There has been change in needs for traffic requirement, services along roads, technology with passage of time since the first edition of manual was made. In order to update the present day requirement &technology improvement this road manual is revised.Effort has been made to cover all the aspects of Urban roads in this revised second edition of Road Manual.

Shri Ravi Mathur, Director(Works) was entrusted with the overall coordination of activities of writing & bringing out the revised manual.

ShriVinayakRai, Superintending Engineer M-34, ShriBijender Kumar Superintending Engineer M-15, ShriSantosh Kumar, Director(Horticulture) &ShriDivakarAggarwal, Superintending Engineer M-11 prepared draft chapters. These drafts were discussed and finalised in various meetings held under my Chairmanship.

For the preparation of this manual we had the blessings and encouragement of ShriArunBaroka, Secretary (PWD).

I would like to express my appreciation of the untiring effort and hard work put in by above mentioned officer in updating the manual.

(Dinesh Kumar)
Engineer-in-Chief
PWD, Govt. of Delhi

PART. 1.
GENERAL FEATURES

CHAPTER-1
ROAD PAVEMENT

1.0 Introduction

The road pavement is the principal structure constituting the carriageway and is meant to carry the wheel-load of the road traffic. Also, it is provided to minimise the intensity of load by distributing it on a larger area and thus making it bearable by the underlying road sub grade.

Broadly speaking are of two types i.e. the flexible pavement and the rigid pavement.

2.0 Flexible Pavement

The flexible pavement generally consists of a series of layers with the progressively stronger material course overlying the weaker ones below. In flexible pavement, the pavement structure is expected to deform in the same way as the subgrade through lateral distribution of applied load with depth. The total load carrying capacity of the flexible pavement depends on the strength of the materials and mixes constituting the layers, the thickness and load distribution characteristics of these layers and finally on the strength of the subgrade. As such the strength of subgrade plays as important role in the design, which in turn is dependent on the subgrade soil type, its moisture content and drainage conditions. Flexible pavement is usually designed by . CBR method as per IRC 37-2012. It generally consists of following courses:

2.1 Wearing Course

The wearing course is the tough and stable top course which comes into direct contact with wheels. This is normally the strongest layer which bears the impact of the traffic load, is exposed to the elements all the time and should preferably be dense, durable, abrasion-resistant and skid resistant. It should also keep out water from the underlying courses and have a texture providing riding comfort.

The commonly used wearing courses are surface-dressing, premix carpet, mix seal, bituminous macadam, dense bituminous macadam, semi-dense asphalt concrete or dense asphalt concrete. When an open-graded premix course is used, provision of sealing to improve waterproofing characteristics may be made.

2.2 Binder Course

This is an intermediate course, which together with the wearing course, is sometimes called the 'surfacing course'. In case of heavy traffic it supports the wearing course and helps to distribute the load concentration onto the granular base-course below.

Bituminous macadam (BM) construction with comparatively low binder content and high voids is generally used for loads upto 2 msa (million standard axle). For higher loads, Dense Bituminous macadam (DBM) is recommended.

2.3 Base Course

For economy in total cost, generally, granular material is used in this course. Conventional water bound macadam, wet mix macadam and similar other granular material construction become useful.

For very high intensity of loading additional thickness of bituminous base-course in the form of BM, DBM may be provided.

2.4 Sub-base (GSB)

It performs the same function as granular base-course (i.e. providing structural strength and distribution of load) except that it is invariably of a lower quality material to effect further economy in construction. In many designs the sub-base may combine the functions of a pavement drainage layer also.

Both, non-processed materials from local gravel or sand-pits and processed materials from quarries may be used. Generally sub-base materials consists of natural sand, moorum, gravel, laterite, kankar, brick metal, crushed stone or slag in conformity with specifications.

2.5 Sub-grade (WMM)

The sub-grade is not a part of the road pavement but is the foundation for both flexible and rigid pavements. It is the uppermost material placed on the available/provided embankment or in cut section, which supports the road pavement structure.

The sub-grade is the top 500mm of the embankment immediately below the bottom of the pavement, and is made up of in-situ material, select soil, or stabilized soil that forms the foundation of a pavement. It should be well compacted to limit the scope of rutting in pavement due to additional densification during the service life of pavement. Subgrade shall be compacted to a minimum of 97 percent of laboratory dry density achieved with heavy compaction as per IS:2720 (Part 8) for Expressways, National, State Highways, Major District Roads and other heavily trafficked roads. IRC:36 “Recommended Practice for the Construction of Earth Embankments and Sub-grades for Road “Works” should be followed for guidance during planning and execution of work.

2.6 Strengthening of Overlays

Sometimes due to heavy unforeseen growth in traffic intensity, the road surface overlays undergoes deterioration before its designed life period. It becomes then necessary to decide about adequacy of overlay and to take strengthening measures. This can be done by undertaking Benkelman Beam Deflection Technique as per IRC 81-1997. Detailed specification and construction methodology for different courses of flexible pavement can be followed as per MOST specification (fifth revision) 2013.

3.0 Rigid Pavement

3.1 *In case of the rigid pavement the thickness is mainly made up of a cement concrete (simple or reinforced) slab. The main structural strength is provided by the rigidity or slab-action and high modulus of elasticity of the cement concrete. Rigid pavement can be designed by following IRC guidelines as given in IRC 58-2011.*

3.2 Load transfer mechanism of the concrete pavements is through beam action and accordingly the concrete pavements are expected to perform relatively better than flexible pavements on weak sub-grades, as these can bridge small soft or settled areas of sub-grades. Design of concrete pavements is fundamentally governed by the flexural strength instead of compressive strength.

3.3 The main purpose of the sub-base is to provide a uniform, stable and permanent support to the concrete slab laid over it. It must have sufficient strength so that it is not subjected to disintegration and erosion under heavy traffic and adverse environmental conditions such as excessive moisture, freezing and thawing. In the light of these requirements, sub-base of Dry Lean Concrete (DLC) having a 7-day average compressive strength of 10 MPa determined as per IRC-SP:49 is recommended. Minimum recommended thickness of DLC for major highways is 150mm.

4.0 *Rigid pavements are more capital intensive and low on maintenance cost. While flexible pavements are cheaper to construct initially but require periodic overlays and are, thus costlier in terms of maintenance.*

The defects in rigid pavements are difficult to rectify while in flexible pavements, the defects are easily rectified. Under the mix traffic conditions on Delhi Road, where 28 types of vehicles are plying, high temperature variations during the year and poor drainage system of the city, the flexible pavements are preferred. The rigid pavements are only adopted in areas which are prone to water logging.

5.0 In Delhi, PWD maintains about 1280 kms of roads. This includes 40 kms of Ring Road, 65 km of Outer Ring Road and rest main arterial roads.

CHAPTER·2
ROAD GEOMETRICS

1.0 Introduction

1.1 Safety and economy are two important goals of any transportation and planning project. The configuration of the road, the dimensions and provisions of different component elements need to be such that transportation is possible in shortest time with the full utilisation of the capacity of the constructed facility. Also the arrangement should technically ensure safety of the road user. Road geometrics lay down suitable guidelines for achieving these goals.

1.2 The Indian Roads Congress have published a set of geometric design standards for Urban Roads in Plains (IRC:86-1983) which are considered to be applicable, by and large, to all urban/suburban situations excepting expressways. The principal features of the above-mentioned standards are quoted in the subsequent paragraphs but it is suggested that in all cases of specific problem the detailed geometric standards outlined in the publication should only be followed.

2.0 Classification

2.1 IRC classifies (IRC 86-1983) the urban roads under the following four categories excepting Expressways for which a separate class has been proposed.

(i) Arterial

(ii) Sub-arterial

(iii) Collector street

(iv) Local streets.

2.2 Arterials

These are roads primarily meant for through traffic and are generally continuous in nature and are co-ordinated with existing or proposed expressway systems. The bulk of traffic between central business district and outlying residential areas or between major suburban centres takes place along them. These may generally be spaced at less than 1.5 Km. interval in highly developed central business areas to about 8 Km or so, in thinly populated sub-urban areas. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections.

2.3 Sub-arterials

These streets are functionally similar to arterials with a lower priority in hierarchy and their spacing may vary from about 0.5 Km. in the central business district to 3 to 5 Km. in sub-urban areas.

2.4 Collector streets

As the name suggests these streets are meant for collection and distribution of traffic from residential neighbourhoods, business and industrial areas and feed them to the sub-arterials and arterials and vice versa.

Collector roads allow full access to and from adjoining areas traversed by them. There are few parking restrictions except during peak hours.

2.5 Local Streets

These form the micro-level network primarily providing access to abutting properties. They do not carry large volume of traffic and allow unrestricted parking and pedestrian movement.

3.0 Classification of Roads as per Street Design Guidelines issued by UTTIPEC, DDA

Street Design Guidelines issued by UTTIPEC, DDA classifies the road hierarchy as under:

(i) National Highways
(ii) Arterial Roads
  (a) Primary Roads
  (b)Other Primary Roads
(iii) Sub Arterial (Collector) Streets
  (a) Primary Collector
  (b)Secondary Collector
(iv) Local Streets

3.1 National Highways

The recommended minimum right of way (ROW) is 90 meters, wherever possible. However, within the city it shall not be less than 60 meters. All the National Highways within the NCTD shall be access controlled upto the Delhi Border.

3.2 Arterial Roads.

These include primary roads with access control and other primary roads.

(i) Primary Roads: Vehicular routes carrying heavy volumes of traffic will generally have free/stable flow conditions with controlled access. The recommended ROW in existing urban area is 60-80m and minimum 80m in the proposed urban extension. While designing roads with 30m ROW and above, provision should also be made for public mass rapid transport system, which may include BRT. Present ring road and outer ring road to be converted to access controlled arterial roads. Cycle tracks should also be constructed along all arterial roads wherever possible.

(ii) Other Primary Roads: Vehicular routes carrying heavy volumes of traffic, BRT route may also be allowed on these roads. The recommended ROW in existing urban area is 45-60m and minimum 60m in the proposed urban extension. Cycle tracks should be constructed along all other primary roads wherever possible.

3.3 Sub Arterial (Collector) Streets

These include primary and secondary collector streets.

(i) Primary collector: These roads will connect major arterial roads and other inter residential district collectors. The recommended ROW in existing urban area is 30-40m and minimum 45m in the proposed urban extension. In addition to this, a separate cycle track should be provided wherever possible.

(ii) Secondary Collector: These roads are intended to collect traffic from local streets within one residential district. The recommended R/W in existing urban area is 18-24 m in the proposed urban extension.

3.4 Local Streets

These are intended for neighbourhood (or local) use on which through traffic is to be discouraged. The suggested ROW is 12 to 20m in the existing and proposed urban area. These roads should be made pedestrian and bicycle friendly by using modern traffic calming designs to keep the speeds within limits as per design.

4.0 Recommended Land Width and design speed

4.1 1RC:86-1983 recommends the following land widths and design speed for the different categories of urban roads:-

Classification	Land Width in Metres	Design Speed (Km/hr.)
Arterial	50-60	80
Sub-arterial	30-40	60
Collector street	20-30	50
Local street	10-20	30

4.2 The design speeds are suggestive only and may be slightly increased or decreased depending on the area traversed i.e. slightly higher values in relatively open suburban areas and lower values in heavily built up areas. On divided highway a higher value may be used. There should not, however, be abrupt large change in the design speed value, the shift being achieved in small steps of 10Km/hr. or so.

5.0 Passenger Car Unit

5.1 The capacity of a road is indicated by the total number of vehicles it can accommodate at a particular level of service. Since, however, the traffic stream consists of various categories of vehicles, these need to be expressed in terms of a common yardstick based on their specific characteristics of mutual interference. It is customary to generally express it in terms of Passenger Car Unit (PCU). The PCU value of a particular category of vehicles is, however, not a constant but seems to vary depending on various factors like vehicle dimensions, the percentage composition of different categories in the stream etc.

5.2 In the Guidelines for Capacity of Urban Roads in Plain Areas (IRC:106-1990) IRC has recommended the following PCU factors for various types of vehicles.

	Table 2.1. PASSENGER CAR EQUIVALENCY FACTORS .		
	Vehicle Type	Equivalent PCU factor Percentage composition of vehicle Type in Traffic stream	
		5%	10% and above
	Fast Vehicles		
1.	Two wheelers, motor cycle	0.5	0.75
	scooter etc.		
2.	Passenger Cars, Pickup	1.0	1.0
	Van		
.3.	Auto-rickshaw	1.2	2.0
4.	Light Commercial Vehicle	1.4	2.0
5.	Truck/Bus	2.2	3.7
6.	Agricultural Tractor	4.0	5.0
	Trailer		
	Slow Vehicles		
7.	Cycles	0.4	0.5
8.	Cycle Rickshaw	1.5	2.0
9.	Tonqa (Horse Drawn Vehicle)	1.5	2.0
10.	Hand Cart	2.0	3.0

6.0 Carriageway Widths

The recommended carriageway widths for different types of single-lane and multi-lane roads as per IRC-86-1983 are as below:-

Table 2.2. RECOMMENDED CARRIAGEWAY WIDTHS

Description	Width in meters
1. Single lane without kerbs.	3.50
2-lane without kerbs.	7.00
2-lane with kerbs.	7.50
3-lane with or without kerbs	10.5
4-lane with or without kerbs	14.0
6-lane with or without kerbs.	21.0

Notes:
1. For access roads to residential areas, a lower lane width of 3m is permissible.
2. Minimum width of a kerbed urban road is 5.5m including allowance for a stalled vehicle.

7.0 Road Capacity

7.1 Design Service Volumes

As per IRC 106-1990 (guidelines for capacity of Urban Roads in Plain Areas) design service volume is the maximum hourly volume at which vehicle 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. Subsequent to the publication of IRC:86-1983 IRC has revised the recommended design service volumes of different categories of urban roads in its publication IRC:106-1990. This aspect has been dealt in detail in para 7 of chapter-4 (Traffic Census on urban Roads -Part-II) of the manual and the design service volumes indicated therein will hold good for urban road design.

7.2 Level of Service (LOS)

Level of Service is defined as the qualitative measure describing operational conditions within a traffic stream and their perception by driver & passengers. For the purpose of determination of road capacity, as a compromise solution, it is recommended that normally LOS "C" is adopted. At this level, volume of traffic will be around 0.7 times the maximum capacity and this is taken as the "designated services volume" for the purpose of adopting design values. .

IRC 86-1983 also suggests that for selecting the cross section of road a higher design period should be taken for small towns and a lower design period for large cities. A design period of 15-20 years should be adopted for arterial and sub-arterials and 10 to 15 years for local and collector streets. The design width of main traffic routes in built up areas should be based on peak hour demands. For rough estimate peak hour flow may be taken as 10-12% of the daily flow.

Urban road capacity usually depends upon road side fringe conditions like parking, extent of commercial activities, frontage access etc. Road capacity expressed in design service volume for urban road is given in table below:

Table 2.3. **TENTATIVE CAPACITIES OF URBAN ROADS BETWEEN INTERSECTIONS**

No. of Traffic lanes and widths	Traffic flow	Capacity in PC Us per hour for various traffic conditions		
		Roads with no frontage access, no standing little cross traffic (Arterial)	Roads with frontage access but no standing vehicle and high capacity intersections (Sub-arterial).	Roads with free frontage access, parked vehicles and heavy cross traffic (Collector)
2-lane	One way	2400	1500	1200
(7-7.5m)	Two way	1500	1200	750
3-lane	One way	3600	2500	2000
(10.5m)				
4-lane	One way	4800	3000	2400
(14m)	Two way	4000	2500	2000
6-lane	One way *	3600	2500	2200
(21m)	Two way	6000	4200	3600

* For three lanes in predominant direction of flow.

7.3 Design Traffic

The design traffic is considered in terms of the cumulative number of standard axles to be carried during the design life of the road. Its computation involves estimates of the initial volume of commercial vehicles per day, lateral distribution of traffic, the growth rate, the design life in years and the vehicle damage factor (number of standard axle per commercial vehicle) to convert commercial vehicles to standard axles.

The following equation may be used to make the required calculation:

$$N_s = \frac{365XA[(1+r)^X-1]}{r} \times F \quad .. (1)$$

where,

N_s= The cumulative number of standard axles to be catered for in the design,

A= Initial traffic, in the year of completion of construction, in terms of the number of commercial vehicles per day duly modified to account for lane distribution
r = Annual growth rate of commercial vehicles
X= Design life in years
F= Vehicle damage factor (number of standard axles per commercial vehicle)

7.4 Lane distribution

On major arterials traffic follows in both the direction but because of number of lanes traffic movement is not strictly channelized, to account for this factor, a lane distribution factor is multiplied to arrive at realistic loading conditions. IRC 81-1997 recommends following lane distribution factors.

(i) Single-lane roads (3.75m width)

Traffic tends to be more channelized on single lane roads than on two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on the total number of commercial vehicles per day in both directions multiplied by two.

(ii) Two-lane single carriageway roads.

The design should be based on 75 per cent of the total number of commercial vehicles in both directions..

(iii) Four-lane single carriageway roads.

The design should be based on 40 per cent of the total number of commercial vehicles in both directions.

(iv) Dual carriageway road.

The design of dual two lane carriageway roads should be based on 75 per cent of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four lane carriageway,, the distribution factor will be 60 per cent and 45 per cent respectively. The distribution factor shall be reduced by 20 per cent for each additional lane.

7.5 Vehicle Damage Factor (VDF) .;

Urban roads are subjected to traffic conditions of mixed traffic. For computation purpose it is essential that different loads are brought to a number of Standard Axle Load repetition. For calculation purpose only the vehicles having laden weight of 3 tonnes or more are considered and VDF is used as a multiplier to bring the different axle load to a number of standard axle load of 80 KN. IRC 37-2012 gives following indicative VDF values.

Table Indicative VDF Values

Initial Traffic Volume in Terms of Commercial Vehicles Per Day	Terrain	
	Rolling/Plain	Hilly
0-150	1.5	0.5
150-500	3.5	1.5
More than 1500	4.5	2.5

8.0 Footpaths

Urban roads are characterised by very heavy volume of pedestrians. Provision of a footpath is necessary for the safety of the pedestrians. The minimum width of footpath should be 1.5 meter. With increased volume of pedestrian, provision of wider footpaths may be required. The guidelines furnished in IRC-86-1983 for width of footpaths are quoted below. As per, UTTIPEC Guidelines, the hight of footpath should not be more than 150 mm above black top, refer drawing of Kerb Stone.

Table 2.4. **CAPACITY OF FOOTPATHS**

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

Those parts of the footpath immediately adjoining buildings, fences, trees and other obstructions, which will not be available for free movement of pedestrian should be disregarded while calculating width required. The width should be increased by 1 meter in business and shopping areas to allow for dead width. Footpaths adjoining shopping fronts should be at least 3.5 meters in width and a minimum of 4.5 m width is desirable adjoining longer shopping frontages. It is desirable that while deciding about the width of footpath with adjoining building, commercial shops, other considerations like type of commercial activities, vulnerability of footpath to encroachment should also be kept in mind.

9.0 Medians

9.1 The primary function of a median is to segregate the traffic in opposite direction and prevent chances of head-on collision. The median area, where provided, may be conveniently used for plantation (to screen opposing headlights), installation of lighting and provision of drainage also. As a general rule medians may be provided on

urban highways with 6 or more lanes. On roads with 4 lanes the pros and cons of such a provision may be carefully examined with regard to the nature of traffic. IRC 86-1983 recommends that provision of median may be avoided where there are significant tidal flow of traffic or where the individual carriageways are inadequate for catering to peak hour traffic volumes etc.

9.2 An absolute minimum width of median in urban areas is 0.90 m and a desirable minimum is 5 meters.

9.3 As far as possible the median should be of uniform width but where change is unavoidable it should be achieved with the provision of a transition of 1 in 15 to 1 in 20. .

9.4 Gap in median/central verge should be kept at minimum possible places. This will ensure long stretches of uninterrupted traffic which in turn will avoid accidents. On gaps in the verge, at intersection or Tee-sections, in order to avoid breaking of central verge depressed nosing concept has been developed and tried with success. The details are given in the sketch **(Fig. 2.1).** It is recommended to reduce height of central verge along zebra crossing to enable pedestrian cross the road without having to climb on the central verge.

10.0 Busbays

In order to avoid an obstruction to the traffic in the main lanes bus bays are preferably provided by recessing the kerbed shoulder. The length of the recess may be 15 m for a single bus stop and additional 15m for each extra bus stop. The depth of the recess shall be 4.5mtr. for single bus stop and 7 mtr. for multiple bus stop. The taper to achieve the above shall preferably be 1 in 8, but in no case shall it be less than 1 in 6. Bus bays should not be located too close to intersections. It is desirable that they are located at least 75m from the intersection on either side preferably on the farther side of the intersection.

11.0 Intersections

11.1 Intersections if not properly designed, act as a potential accident spot. Details like traffic movement, traffic signs, road markings, islands and drainage, horizontal & vertical curves are to be kept in mind while improving road geometrics at intersection. Guidelines may be obtained from IRC 38-1988 "Guidelines for design of horizontal curves for highways and design tables" for facilitating current layout at site and IRC guidelines of design of At grade intersection.

11.2 It is necessary that as a part of quality assurance, intersection geometry should be laid out by AE/AEE in charge of work and cross checked by E.E. himself. Curves should be set out by Polar Deflection Method and layout checked by E.E. himself before allowing to commence the work.

12.0 Camber

12.1 Camber or cross-fall is normally given to provide the road profile a self-draining property. In a straight section of the road the following camber is adopted.

Table 2.5. CAMBER PROFILE

Surface Type	Camber
Gravel or WBM surface	2.5 to 3 percent
Thin Bituminous surfacing	2 to 2.5 percent
High type bituminous surface or cement concrete	1.7 to 2 percent.

12.2 IRC 86-1983 recommends provision of higher value of the camber in areas with high intensity of rainfall and where ponding is feared due to some reason. Also, steeper camber should be provided in kerbed pavements to minimise spread of surface water flow.

12.3 For paved footpaths a cross fall of 3 to 4 percent should be adopted. For verges and unpaved areas the cross-fall should be 4 to 6 percent.

13.0 . Sight Distance

Regarding the provision of sight distance on urban roads, IRC-86-1983 recommends that stopping sight distance should be provided at all points on the road. Stopping sight distance is the total distance travelled by the driver from the time a danger is comprehended by him to the actual stop i.e. the distance travelled during the perception and brake reaction time plus the braking distance. For the purpose of measuring the stopping sight distance the height of the eye should be assumed to be 1.2m and the height of the object as 0.15m.

Table 2.6. SAFE STOPPING SIGHT DISTANCE FOR VARIOUS SPEEDS

Speed (Km/hr.)	Safe stopping sight distance (Meter)
30	30
50	60
60	80
80	120

For other design speeds recommendations of IRC-66-1976 have to be followed.

14.0 Cycle Track

14.1 As per IRC-86-1983 the minimum width of cycle track should be 2 meters. Each additional lane, where required, shall be 1 meter. Separate cycle tracks should be provided where the peak hour cycle traffic is 400 or more on routes with a motor vehicle traffic of 100-200 vehicles per hour. Also, where the number of motor vehicles is more than 200 per hour, separate cycle track are justified even if cycle traffic is only 100 per hour. In general, capacity of cycle tracks may be as below.

Table CAPACITY OF CYCLE TRACKS

Width of cycle	Capacity in number of cycles per hour	
	One-way Traffic	Two-way Traffic
Two lanes (3m)	250 to 600	50 to 250
Three lanes (4m)	Over 600	250 to 600
Four lanes (5m)	----	Over 600

15.0 Lay-byes

To enable drivers to stop clear of carriageway, lay-byes should be provided at regular interval along straight routs. They should preferably be located near public conveniences. They should normally be 3m wide and 30m long with 15m end tapers on both sides.

16.0 Clearance

Standards for lateral clearance of under passes are to be as per the recommendations of IRC in IRC:54-1974 (Lateral and vertical clearance at underpasses for vehicular traffic) and for detailed guidance the same shall be consulted. Some of the broad guidelines are described below.

16.1 Lateral clearance

The lateral clearance from the edge of the pavement should be as. below:-

(a) Pavement without footpath- Minimum clearance from the edge of pavement-
Arterial and sub arterial- 1 meter.
Collector and local streets- 0.5 meter.

(b) Pavement with footpath- No extra clearance beyond the footpath is necessary.

(c) Clearance on divided carriageway-

The left side clearance should be on the same lines as described above. The right sight clearance to the face of any structure in the central median shall be as follows.

Arterial and sub arterial- 1 meter from the edge of pavement

Collector and local streets- 0.5 meter from the edge of the pavement

16.2 Vertical clearance

Minimum vertical clearance on urban roads shall be 5.5 meters.

17.0 Pedestrian sub-way

The minimum width of pedestrian subway is 2.5 metres. The minimum vertical clearance over such subway is 2.5 metres.

18.0 Cycle sub-way

The minimum width of underpass for cycles is 2.5 metres. The minimum vertical clearance for cycle tracks is 2.5 metres.

19.0 Combined cycle and pedestrian sub-way

The width of pedestrian-cum-cycle subway should be 5m minimum for one way traffic and 6.5 metres for two-way traffic. The minimum height should be 2.5 metres.

20.0 Standard Plans for Road Sections

Keeping in view the special needs of urban roads and particularly Delhi roads, UTTIPEC, Delhi Development Authority have prepared street Design Guidelines which may be taken as useful guide. Road Hierarchy Categorization as per UTTIPEC street design guidelines is given in Appendix-1. During implementation of road alignment, road engineers are however advised to keep site condition and requirements in view.

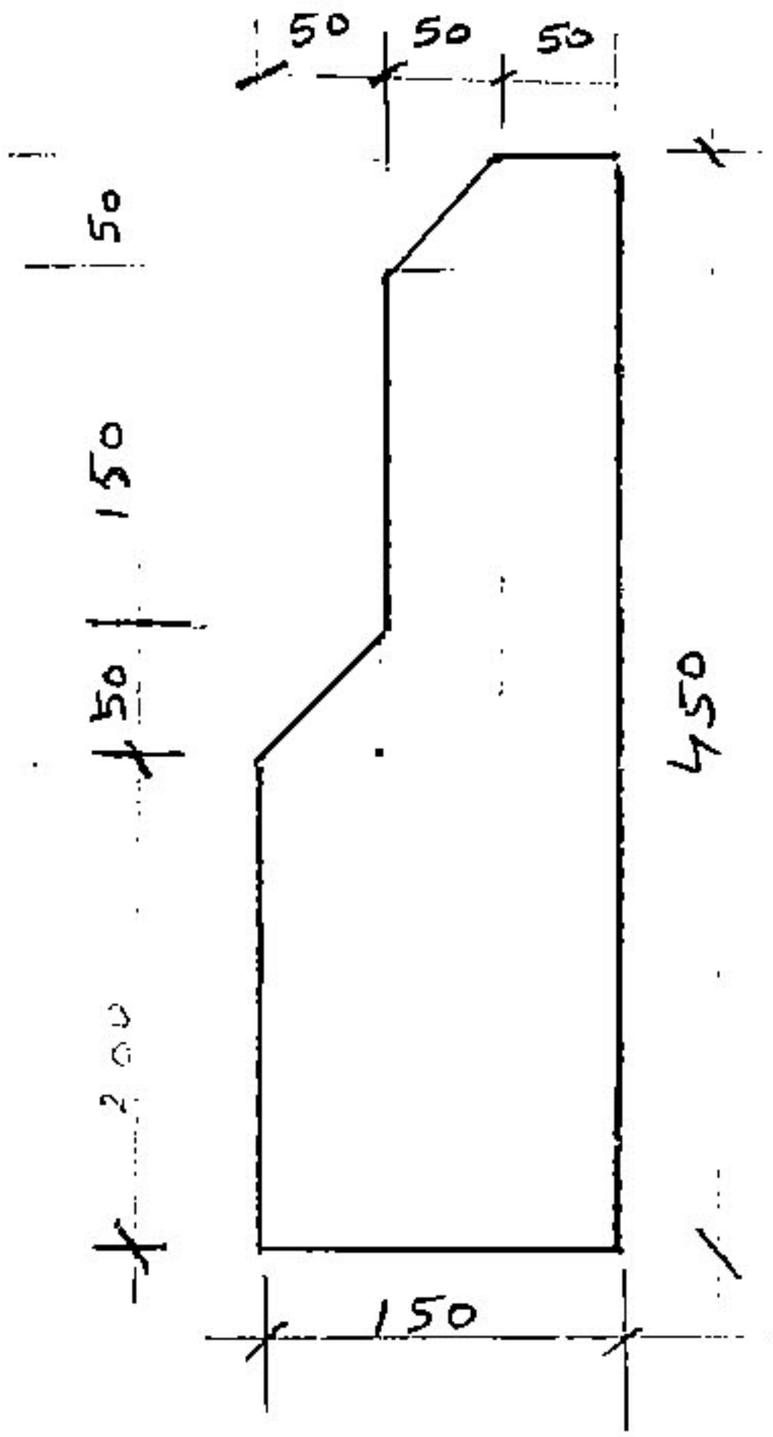
REFERENCES

1. Geometric Design Standards for Urban Roads in Plains - IRC : 86-1983.
2. IRC guidelines for strengthening of flexible road pavements using Benkelman Bean Deflection Technique.
3. Addendum to Ministry's technical circulars and directions on NH and centrally sponsored road & bridge projects published by IRC 1996.

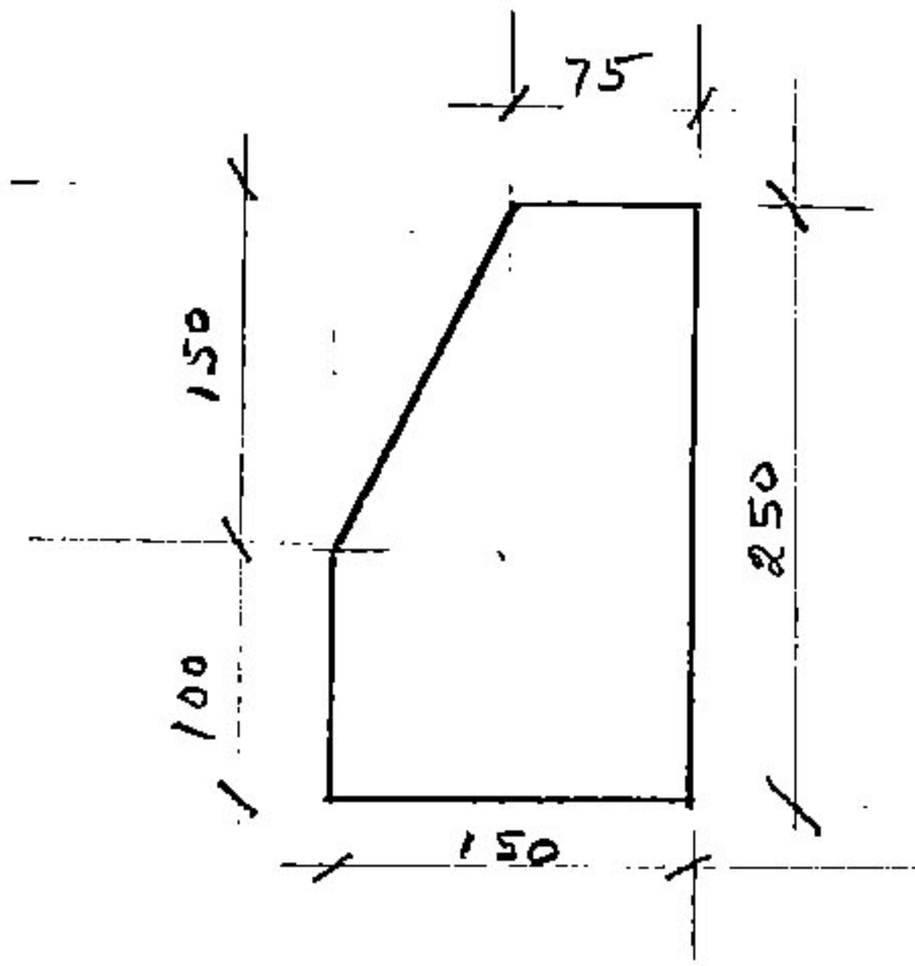
Primary Arterial	Other Primary Arterial	Primary Collector	Secondary Collector	Local Streets	
RIGHT OF WAY	60-80 M	45-60 M	30 - 40 M	18 - 24 M	12 - 20 M
SPEED RANGE	50-70 km/hr	30 - 40 km/hr	20 - 30 km/hr	10 - 20 km/hr	10 - 20 km/hr
SPEED CONTROL	Enforcement and Traffic Calming required	Enforcement and Traffic Calming required	Enforcement and Traffic Calming required	Traffic calming essential.	Traffic calming required
BUSWAYS FOR BRT	Segregated bus ways required where BRT proposed	Segregated bus ways required where BRT proposed	Segregated bus ways required where BRT proposed, at-grade segregation possible on R/Ws above 36 M	No segregated bus lane; but Road may be designated Bus-NMV only if required	No segregated bus lanes or bus operations required; but Road may be designated Bus-NMV only if required
MOTORIZED LANES	2 to 4 motorized lanes per direction, min. 3.3m wide (min. 3.5 for BRT bus ways)	2 to 4 motorized lanes per direction, min. 3.3m wide (min. 3.3 for BRT bus ways)	2 to 3 motorized lanes per direction, min. 3.1m wide (min. 3.3 for BRT bus ways)	No minimum lane width specification.	No minimum lane width specification.
CYCLE/NMV TRACKS	Segregated cycle tracks required ; min. 2.5m wide for two-way movement.	Segregated cycle tracks required ; min. 2.5m wide for two-way movement.	Traffic Calming essential where segregated Cycle tracks are not provided; Cycle tracks to be min. 2.5m wide if block lengths are >250m.	Cycle lanes can work, segregated tracks required where friction & encroachment expected	No special feature for cyclists
SERVICE LANES	Service lanes required.	Service lanes required for low-density residential frontages; for	No service lane required.	No service lane required	No service lane required

		commercial/MU frontages, service lanes not required.			
MEDIANS	Continuous median; all openings and intersections accompanied by signals and traffic calming. (no grade separators within city)	Continuous median; all openings and intersections accompanied by signals and traffic calming. (no grade separators within city)	Intermittent or No median; openings/intersections accompanied by signals and traffic calming.	Intermittent or No median required; For roads where need for Median is felt, issue to be brought to UTTIPEC. Crossings to be traffic calmed.	No medians; traffic calmed crossings, or mini roundabouts

NOTE: Lane Widths have been designated based on desired speed of the road category



KERB STONE FOR
CENTRAL VERGE



KERB STONE FOR
FOOT PATH

CHAPTER-3
ARBORICULTURE, HORTICULTURE AND LANDSCAPING

1.0 Introduction

Construction of a road necessarily inflicts a scar on the natural terrain and unless conscious steps are taken to conceal it and merge it with the surrounding area it may stand out starkly as an incongruity. Also, construction of a road and development of road traffic on it brings in its wake an unavoidable degradation in the environment.

Arboriculture, horticulture and landscaping are some of the devices used by a highway engineer to mitigate the damaging effects of the above and try to restore the balance. Although, the primary quality to be looked for in a road is its functional efficiency with regard to traffic and transportation, all such measures which are taken to improve the appearance of the highway, help it to integrate with the surrounding area and protect the environment are also considered to be the essential attributes of a road.

2.0 Definition

In general terms, the science of road side tree plantation is called arboriculture and that of plantation of shrubs, flowers, plants is called horticulture. All measures taken (including arboriculture and horticulture) in planning, aligning, profile fixing and design to integrate a road with its surrounding area and improve its appearance and effects on environment may form part o(landscaping for road.

3.0 Scope

3.1 Landscaping

3.1.1 The full measure of success of landscaping depends largely on the ability of the planner to induct suitable provisions right at the design stage of the road i.e. in route alignment, in profile (both horizontal and vertical), in the architecture of the road structures etc. to help the constructed facility to become one with the surrounding area and enable the road user to enjoy the beauty of the surrounding without a visual jolt. Much depends on the provision of adequate space between different elements of the road and open areas to enlarge the visual coverage where the same provides a pleasant change in scenery and experience.

3.1.2 However, when a conscious attempt is made to apply the above principles to the usual urban situation the tremendous difficulty of design application comes to the fore. The almost continuous and monotonous nature of urban terrain hardly contain any scope for providing change in scenario. In most of the existing urban areas, with minor exceptions in new townships or new extension areas, it is difficult to make initial design input to enhance landscape value except at an astronomically exorbitant cost of urban acquisition.

Being liberal with open spaces is also not free from danger. In urban situations in developing countries, these open areas are generally prone to encroachment or other forms of economic exploitation of fallow prime land specially if

the enforcement arm of the administration is not strong or sincere enough. Therefore, it is the architecture of the existing construction on both sides of the road which becomes the dominant visual experience for the urban road user and the landscaping of the road and its appurtenances takes a subservient role and requires to be in tune with it at each change of phase.

3.2 Arboriculture/Horticulture

3.2.1 Since land is scarce and costly in urban areas, shoulders and medians will generally tend towards having minimum possible widths with hardly any open land on the sides of the highway thus limiting the scope of arboriculture severely.

3.2.2 However, unlike roads through rural areas the occurrence of a large number of intersections, rotaries and islands in city roads throw up an excellent opportunity for horticultural layout and design to partly compensate for the loss in scope of full-scale arboriculture.

4.0 Landscaping

4.1 The Indian Roads Congress has already brought out a very useful publication titled 'Landscaping of Roads' (IRC Special Publication 21-of 1979) which deals with all aspects of landscaping for roads. The present compilation is not intended to be a substitute of that but seeks to highlight some of the important elements listed in the same specially with emphasis on urban landscaping. For further details the IRC publication may always be referred to.

4.2 Since one of the major tasks of landscaping is to integrate the constructed facility with the surrounding, the first requirement of the planner is to reconnaissance the project area to identify all existing natural and man- made features lying strewn in the area, which may themselves be objects of beauty or have the potential to enhance the beauty of the area. They can be listed as below:-

Natural Features:

- River banks, streams, ponds or natural water bodies, even marshy land.
- Hillocks, ridges or rock outcrops.
- Woodland, groves or even desolate fallow land of adequate area.
- Road length traversing perceptibly rolling or highly undulated area or even area with fault zones where the natural deficiency can be turned into a visual asset by an imaginative landscape architecture.
- Any area with scenic beauty. Man-made Features
- Areas with an imposing building complex or bridge in view.
- Old historical buildings 'and monuments, forts, remains of olden times.
- Famous temples or places of worship.
- Gardens, amusement parks etc.

4.3 The next task is to obtain detailed survey maps for these areas indicating the existing available land and land-use pattern and get an

assessment made regarding the road capacity, transport facility requirement in the area in the near future and on long term basis.

4.4 With the material as above a fresh look may be given to the existing route alignment in the area and abinitio planning done, where needed, to incorporate these features with the best view from road to accentuate, the beauty or magnificence of their presence.

4.5 Since it deals with an abstract subject like aesthetics which is not susceptible. to rigid formulation there can never be any hard and fast rule as to how best to exploit the aesthetic potential of these features and the highway engineer is best advised to go largely by the recommendations of a perceptive landscape architect and a horticulturist of experience in this endeavour. The technical and geometric requirements of the highways can be placed before them and their suggestions for improving the looks and landscape may be incorporated in the proposal.

4.6 Since trees with flowers and foliage and shrubs have always formed an invaluable landscape resource broad guidelines regarding arboriculture/ horticulture are dealt separately in the subsequent paragraphs.

4. 7 Landscaping in Rotaries

The development of big rotaries can be undertaken only with the joint planning and co-operation of the architectural and horticultural cells of the Department.

The general principle of horticulture and landscaping treatment for rotary areas will be in terms of providing a comely garden which is pleasing to the eye in sharp contrast to the hurly burly of road traffic around it. It can be developed mainly by turfing and provision of a pleasing combination of hedges, flowers and shrubs.

Depending on the total area available, in addition to the garden the area can be attractively developed with sculptures, fountains, rockeries, water- channel, miniature bridge and crossing on them and undulating patches of turf. The architecture of the peripheral masonry work, if any, like, railings, pathways, channel shall have to be specially designed keeping an eye to blend with the architecture and material used in the construction of the surrounding area.

4.8 Landscaping in Medians

Since median width available in most urban roads is very small with polluting heavy traffic plying on both sides, excepting plantation of shrubs there can hardly be done any other landscaping work in the median.

4.9 Landscaping of roads near ancient monuments

Delhi is fortunate to have numerous ancient monuments and remains of historical constructions. The road reaches near these spots can be the subject matter of detailed landscape planning to fully exploit the beauty of these monuments. Slight modification or orientation of the alignment or provision of a judicious opening or frontage to the road in these stretches may be an important consideration.

5.0 Arboriculture/Horticultre

5.1 Trees, shrubs and plants on the road side serve a va~iety of purposes.

(i) The trees afford shade the value of which to the road user and the pedestrian can never be overestimated in a tropical country.

The shade helps in bringing down the temperature of the surrounding and prevents the pavement from becoming soft due to overheating with more chances of deformation under wheel-load. It also cuts off substantially the refl~cted light from the pavement the glare of which, when high, blurs human vision and may lead to discomfort and watering of the eyes.

(ii) The dense foliage of trees reduces the reflected light intensity from the pavement, cools the environment and. reduces evaporation of water and wind velocity in different situations;

(iii) With their characteristic shapes, foliage and colourful flowers they add beauty and variety to the scenario, bringing a touch of joy and interest in the road user.

(iv) Besides improving the appearance they also purify the air and serve in restoring atmospheric and environmental balance.

(v) Plants and shrubs when grown on medians, cut off the glare of light from the traffic in opposite direction.

(vi) Trees and shrubs can screen off unsightly vistas such as slums, junk-yards, storage depots etc. in urban/sub-urban locations.

vii) When properly designed they also screen off traffic noise, from residential habitations or sensitive areas like schools hospitals etc.

(viii) With the help of their root system all types of vegetation, specially those grown on slopes, play a significant role in preventing erosion by water and wind. .

(ix) Fruit bearing trees can be a source of food for the society and income for the growers and their plantation may be encouraged whenever conditions are favourable .:

(x) Plantation and horticulture in rotaries/island gardens provide rest area for travelle s, play ground for children and thus help to improve the overall quality of life for the residents of the town.

5.2· Principal considerations for plantation location

5.2.1 General Considerations

Some of the engineering considerations which an average road engineer is well aware of are traffic safety requirement, need of the plantation not fouling with public utilities and services, street lighting etc. The other aspects where care and discretion is required to be exercised relates' to plantation opposite to residential buildings which is usually the case in urban roads. When planted in proximity to buildings it may seriously obstruct natural light entry to the building concerned or even damage its foundation and compound walls. The ultimate

consequence will be laterday requirement of very severe pruning of the tree both on the road side and on the back-side resulting in a very badly. deformed and aesthetically un-acceptable tree form which may not be worth the effort and cost. For the average field engineer the following thumb rules may prove to be quite useful:- .

i) When trees are too close to a building, location should not be selected opposite to entrance gates, entrances to vehicle garages, and opposite to the main front room windows of residential houses.

ii) Effort shall be made to select planting location at least 6 metres away from a street light post, unless the light is centrally hung or there is adequate overhead lighting arrangement. -

iii) Plantation should not be done just below overhead telephone or electric lines.

iv) Plant location should not be very near underground service lines of power, gas, watermains or sewers. These areas may be frequently excavated for repairs/reinstallation etc. which may damage tree roots.

The points mentioned above definitely make the total operation very restrictive but neverthless a way out for selection of a suitable location can still be found specially in planned townships with adequate off-set spaces and well laid out roads

5.2.2 Traffic Safety Requirements for Plantation

Since road side trees can also be hazardous to fast-moving traffic, selection of site for plantation needs a judicious approach and exercise of discretion. Unlike roads in rural areas, urban roads in most cases may not have a defined embankment and the roadside land where plantation is to be carried out generally lies in the same plane as the carriageway for traffic.

(i) Trees on the roadside shall be sufficiently away from the carriageway so that they do not restrict the visibility or become a hazard for stray vehicles.

(ii) Most vulnerable locations in this regard are inside of curved medians, junctions and slopes.

(iii) The height, spread and location of the tree in all cases shall be such that it does not obstruct the clear view of the motorist from highway signs and signals.

(iv) Foliage of the tree should riot interfere with road illumination at night.

(v) For safe operation on traffic lanes the vertical clearance available shall' be a minimum of 5.5 metres. Allowing for the chances' of unchecked growth and swaying of trees during wind and rain, it is recommended that all trees shall be trimmed clear upto 6.5 metre height above the pavement in urban areas. This must be strictly enforced in cities where double decker buses ply.

(vi) Species which naturally grow straight upto a height of at least 2.5 to 3 metre from the ground without branching shall be preferred for obvious reasons.

(vii) Very tall trees or trees with too much of spread and branches shall be avoided as they may Interfere with overhead services, Reduce effective roadway, Become unsafe for passinqs vehicles during storms Obstruct clear view of roadsigns and reduce road illumination.

(viii) The species of trees selected shall be with deep root system as it increases stability of the tree against wind and reduces harm to adjacent public utilities and road pavement.

5.3 Spacing of Avenue Trees

5.3.1 Usually, for each stretch of olantation an arboricultural designs' is made. The spacing between the t~es and their distance from the edge of the carriageway will normally be di~ted by the adopted design. Since each type of tree will have its own verti~1 and lateral growth characteristics and over-all area requirement, no hard and fast rule regarding spacing can be laid down. But this point requires to be paid due attention right from the planning stage as generally it has been observed that in their enthusiasm for' plantation people tend to under-estimate the re=uirement of space interval' and initial 'planning at close interval lead to ultimate over-crowding.

5.3.2 Some of the other important considerations which are made to finally decide upon the spacing are as below:-

Maintenance requirements
Undergrowth characteristics
Clearance intended in design for providing open view and
Provision of occasional clearance to break monotony of
continuous arboriculture.

5.3.3 The designer, however, has to take into account the ~~iJ~y of space and road safety requirement while proposing the design combination and once the design is finalised it should clearly indicate the intended spacing in each stretch. Some broad thumb-rules, however, may be as below:-

For some medium sized trees the interval may be 5 to 6 metres but in most design a minimum spacing interval of 10 to 15 metres may be required between' the trees. When avenue trees are located on kerbed or raised shoulder the distance between the kerb and the nearest point of the tree shall not be less than 1 metre. Where adequate off-set land is available on the side of the road, the nearest row of trees may be at a minimum distance of 4.5 to 5 metres from the edge of the carriageway to be finally constructed as per long term design. (Since it takes a long time to nurture the growth of a tree existing carriageway only should not be taken as a guide). While screening of unsightly areas like slums, junkyards etc. or creating a noise-barrier, trees may have to be planted as close as possible in a continuous row without resorting to pruning of branches at lower level.

When plantation of two consecutive rows of avenue trees is feasible with adequate land-width being available, the row nearer to the carriageway may be of ornamental flowering type whereas the one away from it can be with shade trees.

5.4 Plantation in medians

5.4.1 The main purpose of planting in medians is to cut-off headlight glare from traffic in opposite direction.

Plants and shrubs growing to a short height (1 to 1.5 metre or so) are best suited for the purpose. Larger height of shrubs adversely affect visibility of traffic on the other lane specially in the area near median gaps and are, therefore,not to be encouraged.

5.4.2 If sufficient width is available in the median, the most effective method of planting will be in the form of baffles, Baffle planting is possible only when the width of median is 3 metres or more. A typical baffle layout is shown in Fig. 3.1.

With careful angle of plantation, a baffle may help in cutting off glare from traffic light and at the same time provide clear view of the other lane at places through opening between lines.

5.4.3 Where baffle planting is not feasible because of inadequate width of median, a single continuous line of plantation may be resorted to.

5.4.4. The median planting is required to be kept in shape by frequent trimming so that the vertical growth and the horizontal spread do not interfere with traffic safety.

For a short length near median gap, on each side of the gap and near intersections it may be preferable to discountinue planting or to keep them restricted to a low height only by strictly regulating their growth.

5.5 Arboricultural Design

5.5.1 Growth and survival of trees primarily depend on climatic factors like rainfall, temperature range in the area and the terrain, altitude and soil. Also, in the long run only native plants or genetically similar plants suited to the terrain and the region can successfully thrive and survive. The best course is to get a proper design made for the area in question by a competent arboriculturist and follow the same.

5.5.2 Since the principal purpose of avenue trees is to provide shade and bring about aesthetic improvement of the road facility, trees with deep foliage and beautiful flowers receive primary consideration. Different species of trees shed their leaves or bloom into flowers at different times of the year. The colour of the flowers also may be different. By suitable permutation and combination of available plant material an able arboriculturist tries to prepare a design so that the roadside has the most beautiful combination of colour, flower and foliage and sustain the same for as long a period of the year as possible. This is an expert's job for which the road engineer should seek help of the specialist keeping in view the requirement of each separate zone.

5.6 Broad guidelines for arboricultural design

5.6.1 Apart from having expert's design, the average highway engineer, however, also needs to have some basic knowledge about the general guidelines for selection of trees in order to be able to appreciate and look for an excellent design. In order to orient him towards the general requirement some broad guidelines for design are enumerated below:-

(i) Trees indigenous to the region may be preferred as they will grow in areas with climatic conditions favourable to them. Selection will also be made keeping an eye to the water level in the region.

(ii) However, the above need not be a restricting regulation. In fact a large number of well known ornamental flowering trees that grow in India at present are not native to India and were introduced from other countries with similar climate like Tropical and South America, South Africa, Madagascar, Java, Burma, etc. Suitable innovative designs with exotic plantation are welcome.

(iii) Transplacement from one climatic zone to other (without harsh change) may also be exploited in the design with advantage. Trees which have full growth with abundance of water throughout the year due to heavy rainfall or which grow naturally by the sides of canals and perennial rivers or grow in a moist climate may survive with arrangement of irrigation in comparatively drY climate with less rainfall but they may not grow to the full stature. This new but somewhat stunted variety, nevertheless with its characteristic flower and foliage may some times be prized in an urban situation.

(iv) In urban situations the fast growing trees shall get the preference as they have better chance of growth and survival in inhabited areas.

(v) Nurturing a tree to its full growth is a time consuming effort and their frequent replacement is ruled out. Therefore, trees with long life cycles are preferred.

(vi) Species for plantation in urban areas shall preferably be smog resistant and also tough to withstand harsh environment specially vehicular pollution. The road medians in busy city streets are one of the most polluted areas any plantation has to suffer.

(vii) Trees which drop too many leaves shall not be preferred as in urban areas arrangement has to be made to get the roads swept clean.

(viii) Trees with umbrella or sub-umbrella crowns (like neem, mohua, imli and mango) will be more suitable for plantation in plain area than trees with linear elongated crowns.

(ix) Ornamental flowering trees may be extremely attractive when in blossom. But there should be a word of caution as in most cases the period of blossing is quite short and in rest of the period they may give a bleak appearance. ,#

(x) Trees which are evergreen throughout the year or almost round the year or those which shed their leaves at other times than summer usually get preference in selection in regions with a hot summer.

In general, the so called 'ornamental flowering trees' are mostly deciduous and the ornamental foliage trees' are mostly evergreen. The ornamental foliage trees are therefore, eminently suitable for use as shade trees along highways.

(xi) Trees which have weak wood are considered to be traffic hazards during rain and storm and they may also block traffic for long periods. In view of the above the following species are not recommended for roadside planting.

Eucalyptus.
Millingtonia hortensis
Eugenia Jambolana
Albizzia lebbek
Cassia siamea
Ficus glomerata

Likewise the following species of thorny trees are also not recommehded as they expose the pedestrian and rubber tyred traffic to difficulty in use of the road.

Acacia arabica.

Acacia modesta
Zizyphus jujuba

(xiii) For screen designs (both for sight and sound) deciduous trees may not be suitable. Nearly evergreen trees such as nee m or evergreen trees like mango may be more appropriate for use in combination with low height shrubs at such situations.

(xiv) But the evergreen tree need not.be a must for all locations. For pedestrian roads, trees with heavy but deciduous foliage shall be preferred. While providing deep shade during summer these will permit welcome rays of the sun during winter whe-. the leaves are shed. Otherwise the area may become dar . and desolate during winter and may be shunned by pedestrians These may very well be interspersed with some evergreen trees at interval specially where winter is of short duration and suddenly breaks into warm winds at the end of March.

(xv) For service roads meant for light vehicles and cars only a single or double row of trees with branches and foliage at high level may be planted so that vision at lower level permits wider coverage on sides.

(xvi) Plantation design may be in the form of 'pure avenues' or in a mixed form'.

For double row avenue plantation the ornamental flowering type may be on the inner side of the carriageway. Here skyline is not so important and the criteria of design may be the pleasantness of the mix mosaic, 'The colour elements available for mixing may be orange-scarlet gul-mohars, yellow amaltas, blue jacarandas, scarlet colvilleas, pink legerstroemias, red crythrinas with the designer making

the choice with an eye to their blooming period so that for most of the time round the year the road looks colourful.

Alternative designs, sometimes provided, are with single type flowers in particular stretches of road. In this case however the road stretch may look somewhat bleak in seasons when the flowers are not blooming.

(xvii) In contrast to the above, for the medium to tall outer avenue trees of shade and foliage the main criteria are provision of an elegant back drop and skyline design. Here a particular variety of ornamental foliage may be planted as pure avenues continuous for a stretch and preferably they should be of the same age (i.e. same plantation time). Mixed planting in foliage trees results in a jagged skyline and as the tree tops are at a higher level the unpleasant look is prominently displayed. The identical bole and crown shape, the uniformity and continuity of foliage in depth, colour and density provides a dark sombre green background with an orderly skyline behind the colourful design of the inner flowering avenue trees. Standing as silent sentinels they form a mental demarcation of the boundary line of the road.

With a sparkling combination of colour on the inner line and a carefully varied choice of size and height of background species on the outer line, in an increasing order from stretch to stretch, the highway may represent a symphony of colour and shape slowly rising, from the subdued to the crescendo, to end in an important tourist spot or old architectural monument or a building complex of importance.

(xiii) Where double row plantation is not feasible a more sober design with a single row of alternating flowering and shade trees of medium size may be planted. For such design the same type of flowering and shade trees may be planted for one street or for a length of one or two kilometres on the same road.

(xix) Needless to say that all areas need not be subject to the same design criteria. The roads in business district, the residential areas and approach roads to architectural monuments etc. may have preponderances of different elements like the flowering and shade trees of varying stature. The final say lies with the perceptive designer.

5.7 Arboricultural Screen

5.7.1 As against formal wide-planting design, arboricultural trees can be close-planted so that adjacent trees merge into one another which in effect becomes a sort of hedge with large-size specimens. Even tree forms with irregular outlines can be successfully used in such a design and the planting distance can be reduced to 6 to 9 metres only.

The objectives of screen plantation may be to conceal comparatively unattractive features, to protect the privacy or quiet ambience of residential areas (or sch.o0ls/hospitals) and to reduce noise/dust pollution.

Screen provision will need adequate space and mostly will be in multiple rows. It may be with single species or in suitable combination of different species. For overall better effect the areas adjacent to screen plantation should bear additional touches of a landscape artist.

5.8 Common Available Designs

Keeping in view the general principles and broad guidelines described in the previous paragraphs, a specific arboricultural design for each pocket of soil may be got prepared with the assistance of experts on the subject and the same may be followed. For the roads of Delhi, which is situated in the northern region in India; some common available design combinations suggested for this area a by noted experts are indicated in the Appendix to this note.

6.0 Management of ArboriculturallHorticultural Operations

6.1 General

For a metropolitan city of the size of Delhi, where at any moment of time the on-going arboriculturallhorticultural operations including execution of new projects, maintenancel servicing of existing charges will be quite large, a full-fledged horticultural cell is needed to take care of them. Also, considering the large number of first supply and replacement requirement, running of a few conveniently located nurseries may prove to be cost-effective in the long run.

Location of nurseries, preparation of nursery beds, growing saplings and their transplantation etc. shall be as per sound horticultural practice in consultation with the horticulturist.

6.2 Planting of Trees

6.2.1 For planting of roadside trees in ordinary soil, a pit of 1 m x trn and 1.5 m deep is to be dug. If the soil is not very hard the size may be increased to 1.5m to 2m in diameter.

The pit shall be refilled with a mixture of good soil (if the in-situ soil is not upto the mark) and compost/fertilizer in the ratio of 1 :5 or as prescribed by the fertilizer manufacturers.

6.2.2 Rainy season (i.e. between July to September) is the best period for planting of evergreen and semi-deciduous trees. However, if irrigation is assured, these trees may also be planted in late winter i.e, towards the end o~ February when they enjoy growth in spring under benign temperature and WIth ~he help of irrigation during summer a viable growth can be achieved by the time monsoon arrives. Winter is the best time for planting deciduous trees.

6.2.3 Care during transplantation (preparation of ball of earth around root its handling etc. and initial care of the transplanted sapling, its pruning, stakin~ and

application of fertilisers etc.) shall be as per sound horticultural practices in consultation with the departmental horitculturist.

Tree guards for protection of trees shall be as per the standard design approved by the architect.

6.2.4 Watering of Sapling Saplings planted during rainy season may need two to three weeks to become established. This is a very critical period for the growth of the plant. After a short period the plant may stop growing during winter.

Where uninterrupted irrigation is not assured during summer months the plants should not be irrigated during March. March irrigation will promote the growth of a large number of new leaves with an increased rate of transpiration which the young tree may not be able to sustain during the summer months. It may be better in such cases to taper off the water supply slowly and let the sapling survive on its own resources.

Since these operations are very critical to the success and survival of the entire arboriculture plan, these should not be left to the whims or ingenuities of the Mails or other staff but be implemented and controlled strictly as per the written instructions of the horticulturist.

In cases, where the work is given on contract, the agency must furnish a written 'Watering Schedule' indicating the source of water and the method of watering in each case and follow the same after getting it approved by the horticulturist. The contract shall specify application of water by open-end hose, by gravity or by low pressure pumps so that the water is allowed to percolate into the soil in a concentrated manner instead of creating unnecessary run-off. In case of pumping the pumping pressure shall not be more than 10 psi.

In Departmental maintenance cases, the Mali's and Caretakers shall be properly trained and given a copy of the procedure and watering schedule as approved by the horticulturist. A suggestive general purpose schedule is as below:- .

AGE OF PLANT	WATERING FREQUENCY
(i) One week	Daily
(ii) Three weeks	F.2^{ur} times a week
(iii) One month	Twice a week
(iv) Three months	Once a week
(v) Ten to twelve months	Once a fortnight
(vi) One year	Once a month.

6.3 Maintenance of existing trees and Removal and Replacementof Dead trees Urban road side trees constitute a substantial amount of public investment. Protection of arboricultural assets formed require regular inspection, maintenance and clean-up. .

6.3.1 Inspection of Trees

6.3.1.1 Tree injuries/diseases can be arrested from spreading, accidents can be prevented and expenditure saved if a damage is detected at an early stage.

All avenue trees require to be periodically inspected in order to ensure their health.

There shall be at least one annual inspection of roadside trees and horticultural gardens by a high level officer either just after the rainy season or in the winter.

There shall be at least two inspections during the year by middle-level officers.

There should be regular routine inspection by section in-charges specially for roadside trees to observe safety requirements and identify and mark dead trees/branches etc. for removal.

There shall be unfailingly an immediate inspection by field staff just after storms, heavy showers or cloud burst.

6.3.1.2 Inspection of trees is to be carried out in two distinctly separate operations.

First there should be an over-all observation of the tree from a distance and walking around it in a circle to observe its general health, balance ~f crown, lean or tilt, overhanging or dead branches etc.

This is to be followed by a close observation preferably with binoculars to see signs of fungus infection, formation of holes/rots specially in the trunks or damage to roots or in the bole etc.

All inspected abnormalities and suggested remedials shall be duly recorded in the Inspection Register.

6.3.1.3Trees require to be provided with number plates. The plates should also indicate the common and the botanical name of the tree in the interest of the public.

Name plates should not be driven by nails or tied by wire strings as they injure the bark and provide entry point for fungus. They should preferably be on separate stakes placed alongside the tree.

6.3.1.4 A register of record shall be maintained with information about all trees, their source of supply, date of plantation etc.

6.3.2 Maintenance

6.3.2.1 Routine maintenance work shall consist of selective removal of dead or decaying trees and shrubs, trimming of trees where required for health of the tree or safety of the traffic, treatment of tree injuries, removal of dead stump and debris and undesirable vegetation. For aesthetic reasons all road side trees which are decayed, diseased or damaged by burning shall be removed either in part or full. Trees or branches of trees to be removed shall be identified by a distinctive marking made during inspection. The dead tree shall be cut up to the ground level or at most upto 10cm above ground level in the first instance in the manner and with implements as per sound arboricultural practice. Trees shall be felled and removed in a manner so that the other trees/shrubs are not damaged. Where the same is not possible or permitted the tree shall be removed by sections.

Live stumps of cut trees or branches shall be treated with herbicides the same day it is cut. Application of herbicide shall be as' per the instructions of the manufacturers. In case of branches the removal shall be flush with the tree trunk without any projection which may be unsafe to pedestrians, cyclists or others.

6.3.2.2 Trimming of branches of living trees shall be carried out as per the instructions of the horticulturist. Where no instructions exist all living branches upto a height of 6.5 metres shall be removed by skilled workmen as per sound arboricultural practices using acceptable tools.

6.3.2.3 Dead wood, chippings, cut off parts or other resulting debris shall be removed/disposed off as directed by the road incharge. If local anti-pollution regulations permit they can be burnt but no burning shall be permitted within 15 metres of remaining living trees and vegetation.

6.3.2.4 Although the life of a tree is quite long, with time the planted trees will certainly grow old, decay and die. As growing a new tree to full size takes time, advance action is required to be taken for the replacement of tree by implementing a properly planned and approved replacement plan.

The replacement sapling may be planted r:'i~way between two existtnq trees and the lower branches of the adjacent eXisting trees near the sapling pruned to allow for light and space for its quick growth.

As soon as the replacement tree is grown enough without any danger of dying, the old tree shall be removed to allow for the unrestricted growth of the new tree.

However effective inspection and maintenance may be, mishaps may still occur. It is time that the some form of insurance protection is considered at least against third party damage for accidents/damages from roadside trees.

REFERENCES

1. Manual on Landscaping of Roads- IRC:SP:21-1979
2. Flowering Trees-M.S. Randhawa
3. The Arboriculturists's Companion-N.D.G. James
4. Trees in the Landscape-Graham Stuart Thomas
5. Addendum to Ministry's technical circulars and directions on NH and centrally sponsored roadS bridge projects published by IRC 1996.

Pure avenue plantation with a single variety of flowering tree with different colours may be prescribed for each separate street or stretch of road for a couple of kilometers. Scheme' may be finalised such that plants have varying colour and time of flowering.

2. For outer .avenue only those trees which provide shade arid are of economic value for timber may be planted in pure avenue formation for a good stretch. Trees with an umbrella cirsub-umbrella crown like neem, mahua, imli and ma~go ,shall be preferred to trees with elongated crown.

APPENDIX-II

Tree for Northern regions of India (Plains)
Quoted from IRC **Publication 'Landscaping of Roads**

Albizzia lebbek
Albizzia precera
Alstonia scholaris
Azadirachta indica
Bauhinia variegate
Callostomon lancelates
Cassia fistula
Cassia siamea
Dalbergia sisoo
Jacararida mimosaefolia
Nauelea cadamba
Polyathia lonigifolia
Pongamia glabra
Putrangiva roxburghii
Tamarindus indica
Terminalia arjuna

Tree for Northern regions of India (Hills)
Abies pindrow
Abies webbiana
Albizzia stipulata
Cedrus deodara
Grevillea robusta
Noloptelea integrigolia
Juglans, regia
Olea-ouspidata
Picea smithiana
Pinus excelsa
Pinus longifolia
Platanus orientalis
Poputas alba
Quercus incana
Quereus semicarpifolia
Rhododendren arboreum
Robinia pseudocacia
Ulmus leavigata
Ulmus welllchiana

Trees and shrubs for Delhi regions

Trees	**Shrubs**
Azadirachta Indica (Neem)	Bougain villeas
Alstonia scholaris (Devil's Tree)	Narium Sp
lerminalia arjuna (Arjun)	Jatropha
Cassia-fistula (Amaltas)	Cassia Biflora
Cassia siamea (Kasond)	Cassia levigata
Peltophorum acerifolium (Gulmohar Yellow)	Pomogranate (ornamental)
Delonix regia (Gulmohar)	Ficus sheeta (Pilkhan) Chandni (tebcrria Montana)
Ficus infecitoria (do)	
Polyalthea longifolia (Ashoka)	Lagerstomea indica
Lagerstomea flosraginal (Jarul)	
Acassia auricule fermies (Australian Babul)	

PART. II :
TRAFFIC AND LIGHTING

CHAPTER-4
TRAFFIC SURVEYS ON URBAN ROADS

1.0 Introduction

Traffic surveys are required for determining the exact developmental needs of a road or a road system. All plans, provisions and designs for road works are dependent on the amount of road traffic (existing or expected) it has to cater to. Traffic surveys provide a means of assessment of the magnitude of the road traffic with a reasonable degree of accuracy. The data requirement and the kind of survey required are different for different purposes. As such, traffic survey should be conducted after knowing the exact purpose and object of the study.

2.0 Purpose of Traffic Studies

The traffic census may be conducted with various objectives in mind. For purposes of design and planning, the road authorities require to know the actual situation regarding a number of parameters like volume, speed, traffic composition, axle-load distribution, origin-destination etc.

2.1 Generally, information regarding total traffic volume and its trend of growth will be required for reviewing the existing capacity of roads or fixing the design capacity of future roads.

2.2 The knowledge of traffic composition helps in capacity determination as well as in taking decisions regarding segregation of traffic, provision of separate cycle-track etc., where necessary.

2.3 Information regarding axle-load distribution is essential for the structural design of the pavement and Origin-Destination studies help in assessing the need for provision of a bypass or a circular road or further improvement in capacity of direct routes.

2.4 Similarly, pedestrian counts, speed and delay study and parking need study shall help the planner in taking decisions regarding provision of pedestrian crossings, parking areas and installation of other important control measures to cut out delays in transportation time.

2.5 Some of the above-mentioned studies may need further sub-division depending upon the extent of information required on each aspect of the above. All of them may not be required in each case and when properly designed several of them can be combined in a single census.

3.0 Prediction of Traffic

3.1 In actual life, the amount of traffic generated is controlled principally by human needs and human convenience. The traffic flow, therefore, keeps varying with the change of time, season and other factors.

3.2 Since traffic is, by nature, a variable element, the road planner is interested in knowing not only its magnitude but also its range, the pattern of variation with time and the direction or trend of its growth for prediction of the expected traffic at the end of the design period. Traffic census is carried out essentially for getting an idea of the above.

4.0 Characteristics of Variation

In general, the volume of traffic on urban roads, especially in big cities, is more than that on rural roads. It also exhibits a marked hourly variation over the day, a daily variation during the week and also variation in the traffic trend over the different seasons of the year.

4.1 Hourly Variation during the day

The urban traffic is characterised by at least two distinct peaks i.e. one in the morning when all people need to go to their place of work and once again towards the evening when they return to their residence or go out for shopping, entertainment or other type of activities.

The pattern and profile of growth and the durations of the peak may differ on roads in different work areas. Areas with a large percentage of Govt. offices, schools or similar organisations with regulated timings may exhibit short, sharp and high peaks, while in business districts the peaks may be less high but more sustained with a large horizontal spread in time.

It has also been observed that peak hour volumes are pronouncedly high on direct links or radial roads connecting places by shorter distance than on ring roads. or circular bypasses.

The peak road traffic may also be characterised by marked directional bias.

4.2 Daily variation during the week

If the urban stretch under consideration is reasonably old and stable (where significantly new additions/developmental constructions are not going on) the characteristics of hourly variations on week days may be on expected lines simulating the same profile in the same period of the year. There will, however, be change in pattern during weekends and holidays.

On weekends the morning peak may show late rise, may not reach a sharp peak and may exhibit a long-drawn stable profile over hours specially during winter or in seasons when day time temperature may not be oppressive. During hot seasons there may be a similar sustained peak in the evening hours specially in weak-ends.

4.3 Seasonal Variation within a Year

Both the daily weekday and weekend profile will undergo change, in its average constituent number as well as in time preference when the seasons change from extremes in temperature range to moderates in variation. While the weekend traffic may show marked change, the weekday traffic characteristic will also be affected by variation.

As expected Weather also has a marked influence on traffic flow. On rainy days road using traffic may suffer a down-ward trend.

4.4 Yearly Variation in Traffic Volume

In general, for a growing town with a vibrant economy the volume of traffic generally exhibit a steady trend of increase over the years. This is mostly as a result of increased number of vehicles joining the stream. The general pattern of hourly, weekly and seasonal variations remain similar with only a percentage inflation in number.

4.5 Directional Variation

Although the majority of road sections may be characterised by tidal flow of traffic, there may be sections which for reasons of some inherent imbalance in them or restrictions in traffic rules may exhibit a directional bias or inequality in directional distribution. Imbalance in directional distribution may stand in the way of full utilization of lane capacity and may force the planner to provide more than the optimally required lane-capacity each way.

5.0 General Instructions for Traffic Census in Urban Areas

There is at present no separate guidelines by IRC for traffic census in urban areas. But the suggestions contained in IRC-9-1972 (Traffic census on Non-urban roads) will hold good in a large measure and may, therefore, be followed. However, considering the specific nature of requirement of urban census the following broad guidelines may be helpful.

Excepting for routine periodic counts, in all cases of specific traffic study or investigation for an important project, the actual census work must be preceded by three things as below:-

(i) A preliminary reconnaissance of the area and gathering information about existing land use, presence of any natural/ artificial barrier like a big channel or nallah, railway line, a ridge or embankment dividing the area into zones.

(ii) Existing information about previously collected data on average traffic, peak flow hour/duration, accident information and trend of growth, and

(iii) A discussion/ consultation with local police authorities responsible for traffic control in the area, the concerned town planning authority and transport unit managers.

5.2 For routine census work, keeping an eye on the importance of the area served and the critical nature of traffic in the road section, the entire network under charge may be suitably sub-divided with permanent location point for regular traffic counts. The location of the traffic count station shall be fixed by a senior traffic engineer having knowledge about past traffic trends in the area.

5.3 Traffic census shall be conducted at least twice during a year, preferably once during summer season and again either during winter or during a period when the temperature range is more conducive to human activity(say March/April or October/ November in Delhi).

The census shall not, however, be conducted during any period with abnormal influx of people due to special occasions in the life of the city like Republic Day or some important exhibition or conference.

5.4 For urban situations the peak hour traffic is more critical for consideration than counts at other times. The census shall, therefore, be conducted with careful record of counts during this period.

6.0 Volume Study

This is carried out in order to assess the volume of traffic and its composition. Notwithstanding the usefulness of special studies with specific traffic parameter in mind, information about the total volume of traffic using the road section and its composition form the basic data for having a clear picture regarding the traffic situation at a point. This routine collection of information must be continued for all sections.

6.1 General Purpose Study

As already stated, although the peak hour traffic is essential for most urban designs, it is preferable that routine traffic census for volume study is conducted for a period of full seven days (consecutive) and for 24 hours on each day, specially on ring roads, trunk routes or National Highways, when they form a part of the urban network.

For other important urban roads, excepting trunk routes studies for seven consecutive days from 6 am to 10 pm can be conducted. provided that the peak flows do not either commence before 6 am or linger beyond 10 pm.

For unimportant roads, where average daily flow information is required, three consecutive days' survey may be carried out inclusive of the weekend and at least one weekday. The combination may be Friday, Saturday, Sunday or Saturday, Sunday, Monday provided the weekdays included (Friday and Monday) is not a holiday or special day like market day etc. The weekly average flow estimate in such a case may be as -

$$\frac{5 \times \text{Weekdays (Friday or Monday)} + \text{Saturday} + \text{Sunday}}{7}$$

In case the weekday included is a holiday or market day an extra weekday may be included and the weekly average flow may be estimated as below:-

$$\frac{4 \times \text{Weekday} + \text{Market day} + \text{Saturday} + \text{Sunday}}{7}$$

If the data are to be used only for assessing the capacity of a road section or an arm of the road the count-point may be located at mid-block.

The reporting format for the data may be as per Plate I, Plate II (Daily Summary) and Plate III (Weekly Summary) of IRC-9-1972 (Copy enclosed for reference in Appendix-I, 11.& III to this chapter).

6.2 Study for Intersections

If the data are required to be used for junction design also, the count station has to be located near the junction. For distribution count at a busy intersection separate hand tally forms may be used for each arm of the intersection. The turning movement may also be recorded and the formats for reporting may be as in Appendix-IV and V.

If the data are required only for distribution at junction the count may sometimes be restricted to morning and evening peak hours only (In exceptional cases at midday peak also) using separate field sheets for each half-an-hour.

However, if the data are to be used for signal setting, off-peak counts also are required and it will be preferable to continue the counting from 6 am to 10 pm for the data to be useful for a variety of purposes.

For very complex junctions it may be necessary to resort to noting registration number of vehicles on each arm separately at least during the peak hours and then tally the loggings to record the entry and exit of each vehicle at the arms of the intersection.

6.3 Taking Counts

The volume study can be carried out either by.

(i) Manual method or by

(ii) Automatic method.

6.3.1 Manual Counts

The actual counting work is carried out by a team of enumerators and supervisors deployed in shifts. In case of manual counting the personnel may be divided in 3 shifts of 8 hours' duration. Size of the team is required to be chosen carefully keeping in mind the traffic volume and their speed. Sometimes it is preferable to assign different kinds of vehicles to different persons so that keeping track of each type of vehicle is simple.

Each shift will have a supervisor who will oversee the work. It is very necessary that the supervisor keeps a close watch so that there is no error in counting. It will be ensured by the supervisor that the Identifying information on the top of the sheet for each separate sheet is duly filled up by the enumerator without fail before commencement of entry in the form. Each group will be divided into two parts and separate records will be kept for each direction of travel.

The usual method of manual count is by the five-dash system. In the hourly time column a single vehicle is recorded by making a single vertical stroke and after the passing of every four vehicles an oblique stroke is made for the fifth vehicle. At the end of the shift hourly totals are recorded.

The counting may be done by a press button mechanical system also.

Manual counts can very fruitfully be carried out near intersection or stop signals also. In that case the counting personnel can also note down from time to time the queue length, signal time deficiency, if any, reasons for deadly in flow of traffic and general traffic behaviour in the area in respect of obedience to control signal etc.

Because of its ability and convenience of collecting a sizeable amount of inter-related secondary data, manual traffic count figures and reports are considered to be better and more advantageous by many planning authorities in comparison to data collection by automatic methods. Automatic counting cannot record turning movement, inadequacy or excess in signal duration, (reflected in long queue length or signals without traffic movement), extent of acceptance of control signals etc. Information on these aspects are considered essential for design of channelisation, lane marking, provision of safety measures and design of signals.

6.3.2 Automatic Counts

Manual countings are, however, more convenient for short periods of work. For complex junctions and continuous counting for a long period, the manpower requirement becomes excessive and costly. When counting work is to be carried out for continuous periods of long duration, automatic recording devices become the obvious choice.

Automatic devices may utilise many sophisticated equipment developed based on the principles of magnetic detector, photo-electric devices, contact strip devices and sometimes by plain photography. Many of the implements are quite costly.

A simple automatic device may consist of a flexible detector tube laid and fixed on the carriageway surface which utilises the pneumatic pulse of air generated by the pressure of the passing wheel on the tube which may record one count for the passage of each pair of wheels in succession. Each type of equipment may also have its own weak point for which consideration has to be allowed. For example in the pulse generated counter, passage of a multi-axle vehicle may be recorded as an additional vehicle and in case of the coincidence of simultaneous passage of two vehicles, the count recorded may be only one.

Very sophisticated and advanced varieties of automatic counters have, however, been introduced recently which document many additional information of use such as axle-loads, vehicle classification etc. These can monitor and record information continuously for long periods and even give print out of information. These are costly equipment and can be installed only for complex and important projects.

7.0 Speed and Delay Study

On many occasions traffic studies are conducted to have information regarding the speed of the road using vehicles. The highway planner may need information about different types of speeds like spot speed, running speed and the average journey speed prevalent over different sections of the road. This is usually carried out at different periods of time for four consecutive days.

Reasons for slow speed also require to be identified which may be due to presence of heavily populated locations, congestion, bad surfacing, narrow widths or improper geometrics.

7.1 Spot Speed

It is the instantaneous speed of a vehicle while crossing a particular point on the road.

Measurement of spot speed may be required for enforcing road discipline and ensuring safety. For the designer it is necessary to know the spot speed of the component percentage of vehicles in the stream to assess and fix (or to modify) the speed limit for a particular section of the road considering all aspects of safety.

7.2 Running Speed

Spot speeds do not contain any information regarding the variation in speed which the vehicle may suffer because of congestion, road geometrics etc. along the route. The running speed is the average speed of a vehicle while in motion along a particular section excluding all components of time when the vehicle had came to rest.

This information is essential for determining the capacity of roads and the level of service it is offering to road users.

7.3 Journey Speeds

This is the average speed of the vehicle over the section, the total distance divided by the total time including all stoppages at controlled intersections etc. but excluding voluntary rest periods.

Economic assessment of roads are based on journey time. It indicates the measure of congestion the road suffers, the adequacy of the existing network and may provide guidance in analysing and deciding traffic apportionment of Origin-Destination survey data.

7.4 Some of the speed studies can also be conducted by old manual methods by registration number and recording of time by elevated/moving observer etc. But these may prove to be quite cumbersome and also not very accurate in urban situation. Advanced automatic methods based on the principle of radar, electronic speedometer or cinefilm etc. may be more suitable when one is really in need of accurate speed data for the traffic in a particular section. .

7.5 Assessment of Delay

Measurement of delay can be made as a separate exercise but it is useful to carry it out along with speed studies.

Generally the planner is interested in assessing the delay caused by intersections on a particular section of the road. On the basis of the delay studies locations where existing conditions are not satisfactory and require improvement can be identified.

The delay figure has two contributing components i.e. one being called 'fixed delay' as a result of stoppage at intersection and the other is 'operational delay' as a result of interaction between competing vehicles in a condition of congestion.

Delay measurement is generally carried out by repeated test runs of an observer vehicle at different times and under different conditions of congestion and recording the time for each start and stop with the help of a stop watch. Special record is made when the observer achieves an unhindered run through the section. The average delay is calculated as the difference between the mean journey time of all runs and the meantime of unhindered runs.

8.0 Pedestrian Counts

8.1 In all developing countries where use and ownership of private transport is limited and bulk of the passenger movement is by public transport services, pedestrians moving along the footpath or crossing the road form a large and important component of road user.

8.2 Information on pedestrian counts are necessary for

(i) deciding about the provision of footpath, their width and the structural composition necessary,

(ii) for provision of zebra crossings, signalled crossings and determining their location and timing, and

(iii) for deciding about the location and capacity of sub-ways, foot bridges, guard-rails etc. where they are considered necessary along the network.

8.3 Pedestrian counting is almost always done by manual method (hand tally marks on sheets) and is needed to be carried out only during peak hours. In case of a location where pedestrian congestion may be a continuing feature for the entire day, an additional sample survey during an average representative hour at off-peak period may also be conducted.

8.4 Proper attention and provision of special design facilities shall be required at locations containing a large concentration of pedestrians at one point like near a large block of offices, shopping area, road transport station or railway station etc. Wide footpaths alongwith careful road markings, signalling and even provision of sub-way/foot bridge etc. may be required at such locations.

9.0 Axle-load Survey

On several occasion there arises a need to find out the axle-load composition of the traffic using the road. The data collected through this type of survey are used primarily for design of pavements. Small portable weigh machines and other types of sophisticated automatic counters are available which record the wheel load for the passing vehicles.

10. Origin-Destination (O-D) Study

10.1 It will be good to remember always that at any particular point on the road, traffic congestion is created mostly by vehicles which have really no business to be there. It is in transit, originating somewhere else and on its course to reach some other point. Although in the bulk of the cases this is unavoidable, in several situations some amount of planning and new provision can be made to reduce the congestion. Provision of bypasses, construction of ring roads, augmentation of road capacity to direct routes, etc. are some of the devices to ease the situation. To plan these, an Origin-Destination study is normally required to be carried out.

10.2 The O-D survey will indicate the volume of road traffic between two stations and will help the planner in marking out the most preferable route for them with regard to time and length of travel. Unless, however, specific care is taken to include it in the questionnaire there will be no information about

the actual route travelled and the reason for the same. O-D survey informations are most useful for future planning and new road construction.

10.3 Conducting O-D survey may be a time-consuming affair since even the minimum number of essential questions may run to a considerable length. Generally the methods used are as below:-

(i) Direct roadside interview.
(ii) Use of post cards/questionnaires.
(iii) Registration number method,
(iv) Tags or sticker method
(v) Home interview method.

O-D survey can be conducted directly by stopping the vehicle, interviewing the driver and recording his replies to the questions. From the point of view of the surveyor this is the most simple and direct approach. It has, however, got a few disadvantages. It will involve stoppage of the traffic which is not desirable under any condition and this may discourage and chase away some traffic during the period. And finally it may be found that even after these many remain unanswered.

The other methods without much interruption to traffic may be noting down registration number of vehicles at entry and exit point of the survey cordon or issuing them tags or stickers at entry point to be collected at the exit point. These methods, however, do not provide much scope for recording other information about the traffic.

The post card survey method or home interview method were devised to get over this difficulty. These methods involve more of man-hour and consequently cost but may yield detailed and really useful information.

10.4 It will be ideal if the survey can be conducted to cover the entire traffic i.e. for a one hundred percent sample size for preferably seven consecutive days. In no case, however, the survey will be done for less than three days including the local market day.

In case, however, due to some compelling reason it is not possible to do the same, the survey can be conducted simultaneously at all planned locations once during the peak and again during the normal period. The decision regarding peak/normal hours has naturally to be backed up by a general observation or knowledge about approximate timings of the peak and the normal hours and the periods shall be so chosen 1hat the survey results convey the trends and characteristics of the representative traffic.

As per IRC such a case of sample survey shall cover a minimum percentage of traffic as below:-

Peak hour sample - At least 25% of the volume of traffic,
Normal hour sample - At least 50% of the volume of traffic.

However, if the traffic intensity is very heavy, slight reduction in percentage of sample for survey may be allowed.

Simple traffic count shall, however, be continued through out the entire period (of preferably seven days and in no case for less than three days) so as to enable the sample result to be made applicable for the entire population. Traffic count data for

vehicle type and information regarding origin-destination may be collected using Form 1 & 2 of IRC:102-1988.

11. Passenger Car Unit

11.1 In general, traffic on a road will be of a mixed nature. This characteristic will be quite pronounced in urban roads, where all types of vehicles, fast and slow, with two wheels or with multi-axles may be plying side by side. The capacity of the road to accommodate them will be a complex function influenced by the physical dimensions, speed, interference produced by each type of vehicle and also the percentage composition of each type of vehicle in the total traffic stream. For capacity determination of a road, all types of vehicles are converted into a common unit called Passenger Car Unit (PCU) keeping in view all the above factors.

11.2 The general conversion factors recommended by.IRC:106-1990 (Guidelines for Capacity of Urban Roads in Plain Areas) for urban roads are quoted below:-

Table 4.1. RECOMMENDED PCU FACTORS FOR VARIOUS TYPES OF VEHICLES ON URBAN ROADS

Vehicle Type	Equivalent PCU Factors. Percentage composition of vehicle type in traffic stream.	
	5%	**10% or above**
Fast Vehicles		
1. Two wheelers, motor cycles Scooters etc.	0.5	0.75
2. Passenger Car, Pick-up Van.	1.0	1.0
3. Auto-rickshaw.	1.2	2.0
4. Light commercial vehicle.	1.4	2.0
5. Truck or Bus.	2.2	3.7
6. Agricultural Tractor Trailer	4.0	5.0
Slow Vehicles.		
7. Cycle.	0.4	0.5
8. Cycle rickshaw.	1.5	2.0
9. Tonga	1.5	2.0
10. Hand Cart.	2.0	3.0

12.0 Recommended Design Service Volumes

12.1 At any moment of time a road can handle or accommodate a large variation in the number of vehicles but the service conditions on the road and its ability to cater to smooth and free flow of traffic with average travel speed may change with each composition. As the number of vehicle increases, congestion and interaction between vehicles increases and the freedom of operation of the driver gets more and more restricted. In reality therefore a road has different capacities at different levels of

service. The service levels have been designated as A, B, C etc. upto F. Level of service A represent the best operating condition (i.e Free Flow) and the level of service F represent the worst condition (i,e Forced or break-down flow). For purposes of design and assessment of adequacy of a road the experts have recommended the capacity at service level 'C' to be generally taken into account.

12.2 Also as the road capacity of urban roads is greatly influenced by road side fringe conditions i.e parking, extent of commercial activities, frontage access rtc. These conditions affect the level of service and capacity. The urban roads have been subdivided into the following categories based on fringe conditions:.

i) Arterials Roads: No frontage access, no standing vehicles and very little cross-traffic.

ii) Sub-arterials: Frontage development, side roads, bus stops, no standing vehicles, waiting restrictions.

iii) Collectors: Free frontage access, parked vehicles, bus stops, no waiting restrictions.

12.3 Design service volumes for the above categories of roads have been recommended by IRC:106-1990 as below:-

Table 4.2. RECOMMENDED DESIGN SERVICE VOLUMES (PCU's Per Hour)

S.No.	Type of carriageway	Total Design service volumes		
		Arterial	Sub-Arterial	Collector
1.	2 lane (One-way)	2400	1900	1400
2.	2 lane (Two-way)	1500	1200	900
3.	3 lane (One-way)	3600	2900	2200
4.	4 lane Undivided (Two-way)	3000	2400	1800
5.	4 lane Divided (Two-way)	3600	2900	--
6.	6 lane undivided (Two-way)	4800	3800	--
7.	6 lane Divided (Two-way)	5400	4300	--
8.	8 lane Divided (Two-way)	7200	--	--

13.0 Computation of Design Traffic

13.1 A road pavement is designed or strengthened with a particular design life in view. Normally the design life is taken as a minimum of 10 years but provision is made for progressive construction with strengthening in stages. Since the road traffic is expected to increase during the period, based on the prevailing trend of growth a computation is generally made to provide for a capacity and structure adequate to meet the traffic load for the design period.

13.2 Usually the following formula is used for traffic projection on main through routes.

$A = P (1 + r)^{n+y}$ Where

A = Number of vehicles per day.

P = Number of vehicles per day at last count.

R = Annual rate of increase in the number of vehicles in percent

N = Number of years between the last count and the year of completion of project.

Y = Design life proposed in years.

14.0 Improving the capacity of urban Roads

14.1 The IRC guidelines for capacity of urban roads in plain areas (IRC: 1 06- 1990) suggest a number of measures for improving the capacity of urban roads. The suggestions made are quite useful and the relevant portions are quoted below for guidance.

14.2 In the event of traffic on a road section exceeding the design service volume at the desired level of service, the operating conditions will deteriorate. If so, the available practical capacities can be improved through application of traffic engineering techniques, besides better enforcement.

Some of the measures that could be considered for enhancement of capacity are as under:-

i) Prohibiting on-street parking of vehicles, and simultaneously developing off-street parking facilities.

ii) Segregating the bi-directional traffic flow by provision of central verge/median.

iii) Provision of segregated right-of-way for slow-moving vehicles such as animal drawn carts, rickshaws/tongas etc.

iv) Imposing restrictions on the movement of animal drawn/ other slow moving vehicles, and/or heavy commercial vehicles on busy arterials/ sub-arterials during selected periods, specially the peak hours.

v) Reduction of road side friction through control of abutting land-use and road side commercial activity.

vi) Provision of adequate facilities for pedestrians and cycles:

vii) Banning certain conflicting movements at major intersections particularly during peak hours;

viii) Controlling the cross-traffic and side-street traffic by regulating the gaps in medians and

ix) Improving traffic discipline such as proper lane-use and correct over-taking through appropriate road markings, education and publicity.

REFERENCES

1. Traffic Census on Non-Urban Roads - IRC:9-1972.
2. Traffic Studies for Planning Bypasses around Towns- IRC:102-1988.
3. Guidelines for Capacity of Urban Roads in Plain Areas-IRC: 106-1990.
4. Urban Traffic Engineering Techniques - Ministry of Transport/Scottish Development Department (HMSO-1966).
5. Roads and Traffic in Urban Areas- Institution of Highways and Transportation with the Department of Transport (U.K.).
6. Highways- CA O'Flaherty.

APPENDIX-1

Date and Day of Week TRAFFIC CENSUS Road Classification_____

Direction of Traffic UP/DOWN Field Date Sheet ____ Kilometrage/Mileage___

From …… Rout No. (If any) _____

To ……. Distance State

Type of Vehicle Hour of Count	Cars, Jeeps, Vans, Three etc.	Buses	Trucks	Motor Cycle & Scooter	Animal Drawn Vehicles	Cycles	Others (Specify)	Remarks Including Weather Conditions
1	2	3	4	5	6	7	8	9
From…. Hrs. To…….Hrs.								
Hourly Total								
From….Hrs. To ……. Hrs.								
Hourly Total								
From…..Hrs. To …… Hrs.								
Hourly Total								
From…..Hrs. To …… Hrs.								
Hourly Total								
From…..Hrs. To …… Hrs.								
Hourly Total								

Notes :

1. Record Traffic volume In columns 2 to 8 by making tallies In the form of vertical strokes for first four vehicles and drawing an oblique stroke for every 5th as shown within brackets (...)
2. Some roads carry appreciable volume of other traffic like cycle lckshaws record the volume of such vehicles in column 8 after specifying the vehicle type.}
3. The hour of count should be entered before the start of enumeration. P.M. hours should be recorded after adding 12 to the actual hour.
4. For example 2p.m. should be recorded as 14.00 hours. If felt necessary by highway authority, this column could be sub-divided into two for recording the volume of "Pneumatic-tyred" and Iron-tired vehicles separately.

Name & Signature of Enumerator with date.....

(Extract from IRC-9-1972)

Name & Signature of Supervisor with date.....

APPENDIX-II

Date and Day of Week TRAFFIC CENSUS Road Classification_____

Direction of Traffic UP/DOWN Field Date Sheet ____ Kilometrage/Mileage___

From …… Rout No. (If any) _____

To ……. Distance State

Period				Fast Vehicles					Slow Vehicles				
From		To		Cars, Jeeps, Vans, Three Wheelers	Buses	Trucks	Motor Cycle and Scooter	Total (5 to 8)	Animal Drawn Vehicle	Cycle	Others (Specify)	Total (10 to 12)	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Total for the week													
Average Daily Traffic for the Week													

(Extra from IRC-9-1972)

Name & Signature of
Supervisor with date

TRAFFIC CENSUS Road Classification

Traffic Summary Kilometrage/Mileage

Route No. (If any) District State

Date and Day of Week _____ _____

Direction ofTraffic.UP/Down From ... to __

	ENTERING THE JUNCTION FROM																Total	Remarks
	A				B				C				D					
	L	S	R	T	L	S	R	T	L	S	R	T	L	S	R	T		
A.M																		
6-7																		
7-8																		
8-9																		
9-10																		
10-11																		
11-12																		
P.M																		
12-1																		
1-2																		
2-3																		
TOTAL																		
AVIHR																		

Under line peak hours in red ink

L- left S- Straight

R- Right T- Total

Sign and date of supervisor

CHAPTER-5
ROAD MARKINGS

1.0 Introduction

Roads are not meant simply to carry the traffic but to carry it with maximum possible efficiency, speed and safety. Although the structural and technical adequacy of the road is an important contributor to the achievement of the above, finally it is only with the active co-operation and self-discipline of the road traffic the above object can be realised in full measure. Also this requires almost a continuous point to point guidance and reminder to the traffic regarding the limitations of the facility under use and the requirements of road discipline. One of the best means of achieving the above is through road markings. The road markings are thus a device for providing continuous information, control and guidance to the road user. The availability of this guidance assumes greater importance when the traffic on the road is of a mixed and heterogenousnature as in the city roads in this country.

2.0 Definition

Road markings can thus be defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users.

3.0 Functions

Keeping in view the objectives mentioned above, it can be said that *t*he following specific functions may be performed by the road-markings:-

(i) The markings are used to delineate the traffic lanes and indicate the lateral clearance available.
(ii) May be used to convey tapering or gradual change in available width of lane due to constraint or transition to different width.
(iii) To clearly demarcate the hard shoulders when the shoulders have black topped surfacing similar to the main carriageway.
(iv) Todefine the nature of boundary between different traffic lanes.
(v) To guide the traffic in aligning for the right lane for its intended direction ofturn.
(vi) To provide warning regarding approach of intersection, cross-traffic, pedestraincrossing etc.

One of the great advantages of road-markings is that, unlike road signs and hoardings, it conveys the required message to the driver without distracting his attention from the road. They also have the advantage that they are not likely to be obscured, and can provide a continuous message.

4.0 Road Marking Code

4.1 For establishing a uniform system of road marking in the country the Indian Roads Congress had brought out in 1970 a 'Code of Practice for Road Markings' which was revised in 1997 and which shall be followed in all cases. The present set of guidelines does not purport to be a substitute for the same but only highlights some of the important elements in it. For use

of other materials specially thermoplastic paints as well as fordetailed specifications for actual laying work, the 'Specification for Road and Bridge Works' of the Ministry of Surface Transport may be followed. Salientfeatures of the same are also quoted in the present notes. A few sketches of the important marking patterns are enclosed but for a comprehensive list of the same the IRC-35 shall be referred to.

4.2 Materials for Road Marking

Paints used for road markings should conform to Grade I of IS:164, with the proviso that these shall have a wear resistance of at least 4 hours under accelerated laboratory test. These paints are not very bright and as such fail to catch instantaneously the driver's eyes and also have a short service life. Hot appliedthermoplastic paint are therefore used instead of ordinary paints for better visibility and longer service life.

4.2.1 Improved night visibility is obtained by the use of minute glass beads embedded in the pavement marking materials to produce a retroreflective surface (i.e which appears luminous at night under normal head lights) and the same are recommended for use in markings.

4.2.2 The use of reflective materials or thermoplastic paints is also recommended for construction zones where road or bridge works are under construction, for proper traffic guidance and safety.

4.3 Other Materials

4.3.1 Pavement markings may also be in the form of pre-fabricated sheet materials (e.g. plastic sheets) which may be attached to or set into the pavement surface in such a way that their upper surfaces are flush with the pavement surface. Such materials should have good durability, uniform thickness and should neither spread nor peal off under the weight of heavy traffic.

4.3.2 Cold rolled or glue down plastic stripes which have an adhesive backing have primarily been used for cross walks and stop lines on bituminous pavements in high density urban areas. Their other applications include lane and centre line marking on bituminous where the plastic stripes can be rolled into the bituminous surface during the process of its compaction. These however, should be used in well lit areas so as to maintain the reflectivity of the markings at a desirable level.

4.3.3 Pre-fabricated tape markings with an adhesive backing can be used for temporary markings for guidance of traffic during construction and for semi-permanent markings, such as word message/symbols, parking stalls and parking lot markings.

4.3.4 Reflectorised stripping powder can provide instant markings of cross walks, school zones and other legends. The materials has glass beads distributed throughout and is applied to the pavement by a special striper with a proper flame that melts the powder in air just above the surface and then binds it to the pavement surface.

4.3.5 Metal and plastic inserts and felt marker units in or on the pavement surface are used principally in urban areas where paint markings are rapidly worn out under heavy traffic volumes and frequent repainting is not only costly but causes undue traffic delays.

4.3.6 Non-reflecting road studs used for marking the limits of pedestrian crossings and approaches thereto and of parking bays, may be made of stainless steel or an appropriate form of plastic. Reflecting road studs may be either a reflex lens type or

solid white beads. They may be unidirectional or bidirectional and the lenses may be of red or white colour according to the requirements. Solid reflecting studs may be either circular or rectangular in shape. These are made of either ABS (Acrylonitrilc Butadiene Styrene) or die case aluminium alloy.

4.4 Colour

4.4.1 White colour shall be used for carriageway marking except for (i) Lines indicating parking restriction,(ii) obstruction approach markings and (iii) no passing zone marking, where yellow colour (conforming to IS colour NO.356 of IS-164-1981) shall be used.

4.4.2 Yellow colour may also optionally be used for continuous centre-line or barrier-line marking.

4.4.3 White alternating with black colour shall be used for kerb and object markings.

5.0 Types of Markings

Depending upon the surface on which the road marking is carried out or the specific function that a particular type of marking can perform, road markings are generally categorised under the following broad headings.
·(i) Carriageway Markings
(ii) Object Markings.

5.1 Carriageway Markings

These are general markings on the carriageway itself used to convey traffic movement restrictions, parking restrictions, turning, pedestrian crossing zones etc. The messages are conveyed to the driver by means of a set of agreed symbols and the width of the line is selected with an eye to prominence and visibility and the degree of emphasis of the message. According to their function the carriageway markings may also be sub-categorised as below:

(i) Longitudinal Markings:-
- Centre lines
- Traffic lanes
- No passing zones
- Warning lines
- Border or edge lines
- Cycle lane markings
- Bus lane markings

(ii) Markings on Intersections
- Stop lines
- Giveway lines
- Markings on approaches to intersection
- Markings on speed change lanes
- Direction arrows
- Protected right turn lanes
- Marking on rotaries
- Box Markings
- Cyclist Crossings
- Pedestrian crossings
- Continuity lines

(iii) Markings at hazardous locations
- Carriageway width transition marking
- Obstruction approaches marking
- Road - rail level crossings
- Check barriers

(iv) Markings for Parking.
- Parking space limits
- Parking restrictions
- Bus stops

(v) Word Messages
- STOP
- SLOW
- BUS
- KEEP CLEAR
- SCHOOL
- RIGHT TURN ONLY
- EXIT ONLY
- SPEED 25 (or other specified)

5.2 Object Markings

These are markings to indicate the presence of obstruction on or near the carriageway and forewarn,the driver of the approaching hazard. Typical of them are the presence of supports for road overbridges, signs/signals, masonry/rock projection, traffic islands, narrow bridges and culverts, head walls, poles, trees etc. According to their intended' functions the object markings may be sub-categorised as below:

(i) Objects within the carriageway
(ii) Objects adjacent to the carriageway
(iii) Markings on Kerbs

6.0 Longitudinal Markings

6.1 General Considerations

The significance and interpretation of the different patterns of markings used shall be as contained in IRC-35. The message conveyed by some of the common representations are as below.

6.1.1 Broken lines are permissive in character and may be crossed with discretion, if traffic permits.

6.1.2 Solid lines are restrictive in character and indicate that crossing is not permitted except for entry or exits from the side roads or premises or to avoid a stationary obstruction.

6.1.3 Double solidlines indicate maximum restrictions and are not to be crossed except in emergent usage.

6.1.4 When there are double lines, one broken and one solid, the solid line may be crossed, with discretion, if the broken line of the combination is nearer to the direction of travel. Vehicles from the opposite direction of travel are not permitted to cross the solid line.

6.2 Centre Line

6.2.1 On undivided two-way roads, centre line separates the opposing streams of traffic and facilitates their movements.

6.2.2 In general, the centre-line, as the name signifies shall be in the middle of the carriageway. But in certain circumstances the centre-line may be located off-centre (such as in urban roads with parking permitted on one side, in carriageway width transition, in urban roads with an odd number of traffic lanes with the extra lanes allotted to the predominant direction of flow, in carriageway with odd number of lanes, on vertical and horizontal curves with limited sight distance, on sharp curves with extra widenings etc.).

6.2.3 On unimportant roads with less than 5m wide carriageway, centre-lines are not considered undesirable as these entail discomfort and hazard .In such cases centrelines may beprovided in short stretches near approaches to busy intersections, pedestrian crossings, level crossings, in horizontal and summit curves with limited sight distance and on locations where driver's visibility is reduced e.g by frequent fogs.

6.2.4 On undivided urban roads with at least two traffic lanes in each direction, the centre-line marking shall consist of either a single solid line 15 cm wide or double solid lines 10 cm wide separated by a space of 10 cm.

6.2.5 On urban roads with less than four lanes or on those roads having four lanes and on which parking is permittedreducing the effective operational width, the centre-line shall consist of a single broken line of 15 cm width of 3 metre segments and 4.5 metre gaps between segments.
On curves and in approaches to intersections,the gap shall be reduced to 3 metres.

6.2.6 A line marking the centre of a one-way street is a lane line and shall be a broken line.

6.2.7 If the centre-line is to be painted on the pavement on the approaches to a bridge, it shall be continued over the bridge provided that the width between the kerbs in the bridge is 6 metre or more. If the width is less than 6 metres, the centre-line marking on approaches shall be discontinued from a distance of 30 to 35 metres prior to abutment on each side of the road.

6.2.8 Double line shall not normally be painted on a two-lane bridge except where restricted visibility makes it hazardous to overtake.

6.3 Traffic Lane Lines

6.3.1 Further sub-division of wide carriageways into separate lanes on either side of the centre line helps to regulate traffic into proper lanes and curbs the meandering tendency of the drivers, thereby promoting safety and ensuring maximum capacity. At intersections and on approaches thereto, marking of traffic lanes eliminates confusion and facilities through and turning movements.

6.3.2 Trafficlane lines shall normally be single broken line. Their width shall be 10cm.

6.3.3 In urban areas, the length of the line segment shall be 1.5 metre with a gap of 3 metre on straight reaches. On curved reaches andoin approaches to intersections the gap shall be reduced to 1.5 metre length.

6.3.4 Solid lane lines can be used in approaches to intersections or in other areas if lane changes are to be restricted.

6.4 Marking for No Overtaking Zones

6.4.1 No overtaking zones shall be established on submit curves, horizontal curves and elsewhere on two and three lane highways where overtaking manoeuvres must be prohibited because of restricted sight distances or other hazardous conditions.

6.4.2 On undivided highways with more than 3 lanes,there is hardly any need for vehicles to cross the centre lines for overtaking. The double solid centre line prescribed for such highways is to be regarded as continuous no-overtaking marking which is not to be crossed on either side.

6.4.3 A no-overtaking zone shall be marked by a solid yellow line along the centre. In case of double yellow lines the left hand element shall be a solid barrier line, the right hand element will be either a normal broken centre line or a solid barrier line governing the traffic from the opposite direction. Where a solid barrier line is to the right of broken line the passing restriction shall apply only to the opposing traffic.

6.4.4 The width of each line shall be 100 mm . These shall be separated by 100 mm.

6.5 Border of Edge Lines

6.5.1 These indicate carriageway edges of rural roads which have no kerbs to delineate the limits upto which driver can safety venture. This continuous guideline makes night driving comfortable particularly during inclement weather.

6.5.2 The pavement edge lines are desirable at the following locations:

(i) Where the shoulders is paved and is of similar texture and colour to the main carriageway;
(ii) In advance of and near narrow bridges and around sharp curves;
(iii) Where obstructions on the shoulder are close enough to constitute a hazard to the motorist;
(iv) On pavement width transitions;
(v) Along lengths which are prone to fog and mist.

6.5.3 Carriageway edge lines shall ordinarily be provided only on roads with more than two lanes. These shall be in the form of a single continuous white line placed on the carriageway 150 mm from the edge. On multi-lane road with central median the carriageway edge line shall be 150 mm wide and on multi-lane roads without medians the width may be 200 mm . Where flush kerbs are provided, the edge lines should be superimposed.

6.5.4 The border or edge line markings should not be carried across the mouths of side roads.

6.5.5 The markings should preferably be reflectorised or incorporate crusted calcined flint or other such reflecting materials.

6.6 Bus Lane Marking

6.6.1 The lanes reserved for the buses, without physical separation should be provided with white line as bus-lane markings on the carriageway (Fig.8). Generally a basic width of 3 metres is required for a bus lane. The distance is measured from the edge of the kerb to the centre of the continuous white line of 250 mm min. width. A gap in this white line should be left, adjacent to each side road.

6.6.2 The legend BUS LANE should be marked on the carriageway across the lane at its commencement and repeated after each junction. Where junctions are more than 300 metres apart, this legend should be repeated between junctions at approximately 150 metres intervals.

6.6.3 A 250 mm wide broken line of 1000 mm gap should be laid from the kerb to the start to the full width lane to deflect other traffic from the bus lane. The traper of laying this broken line should not normally exceed 1:10.

6.6.4 Where a bus lane commences just beyond an intersection, adequate length should be left for the traper to commence at the intersection so that the inclined line does not extend across the intersection mouth. Similarly to allow traffic to position itself correctly on the carriageway, the continuous bus lane should end in advance of any intersection with major left-turning flow.

6.7 Bicycle Lane Marking

6.7.1 Bicycle Lane markings should be provided when a portion of the carriageway, being used by motorised vehicles, is earmarked for exclusive use of cyclists.

6.7.2 The bicycle lane marking shall consist of a 150 mm thick solid white line parallel to the kerb of the carriageway. The width of the lane shall be determined by the number of bicycles using it and should be in accordance with IRC: 11-1962.

6.7.3 The cycle symbol shown in IRC:35-1997 should be marked on cycle lanes.

For further details and all other situations, specially for provisions in respect of Warning lines, etc. ,the detailed guidelines contained in IRC-35 shall be referredto and followed.

7.0 Marking at Intersections

7.1 General Considerations

Carriageway markings within and in the neighbourhood of an intersection ensure orderly movement of traffic. Markings are resorted to even at unimportant intersections. The type of carriageway marking for a particular intersection is the function of several variables such as speed characteristics of traffic, availability of space, etc. The Engineer should choose the layout for a particular location depending upon the conditions at site. The markings for the various intersection types illustrated in IRC:35-1997 are typical only. The precise layout may be adjusted to suit the design of intersection under consideration. The details of various intersection markings are described in IRC: 35-1997. Details of some of the important markings are given below.

7.2 Stop Line

7.2.1 Stop line indicates the position beyond which the vehicles should not proceed when required to stop by traffic police, traffic signals or other traffic control devices. Stop lines shall not be used unless traffic control by any one of these means exist. Stop lines should either be parallel to the intersecting roadway or at right angles to the direction of approaching vehicles.

7.2.2 Single top line shall be solid white transverse line 200 mm wide on urban roads and 300 mm wide on rural roads.

7.2.3 Double stop lines shall consist of two continuous lines each 200 mm wide spaced 300 mm apart and supplemented by a stop sign in accordance with IRC:67-2012 and a word message "STOP" marking on the carriageway in accordance with IRC:35-1997.

7.3 Give Way Lines

7.3.1 The prescribed marking consists of two broken lines laid side by side, each comprising 600 mm line segments and 300 mm gaps. The lines are 200 mm wide and are spaced 300 mm apart. The marking is laid across, the minor roads at intersections which are not controlled by stop signs, traffic signals or the police.

7.3.2 The Give way lines shall be supplemented by the hollow triangular Give Way approach marking and a Give Way road side signs. The hollow triangular marking should not be used elsewhere. The marking should normally be located with its base 2.0 to 2.5 m from the transverse marking.

7.3.3 Details of GIVE WAY lines are shown in IRC:35-1997.

7.4 Pedestrian Crossings

7.4.1 Crossing of the carriageway by pedestrian, only at the authorised places minimises the confusion. As a result of this, the number of pedestrian casualties is reduced and the tendency to joy walk is curbed. The success of pedestrian crossings in controlling both vehicular traffic depends to a greater extent on where and how they are marked.

7.4.2 Pedestrian crossings shall be provided at important intersections where conflict exists between vehicular and pedestrian movements. The site should be so selected that the pedestrian are subjected to minimum inconvenience and the vehicular traffic too is not interrupted very often.

7.4.3 The location of pedestrian crossing at intersections should fulfil the following conditions to ensure safety of traffic.

(a) Adequate visibility so that the driver of approaching vehicle has clear view of the personson thepedestrian crossing and on the pedestrian footpath;

(b) Sufficient space on the footpath for the pedestrians to wait; and

(c) Freedom from obstruction such as trees, sign posts, lamp posts, etc, in the path of pedestrians at either end of the pedestrian crossing.

7.4.4 For dimensions and positioning of pedestrian crossings, IRC: 103-2012 "Guidelines for Pedestrian Facilities", may be referred.

7.4.5 At intersections, the pedestrian crossings should invariably be preceded by a stop line at a distance of 2 m to 3 m for unsignalized intersections and at a distance of 1 m for signalized intersection.

7.4.6 The width of the Zebra crossing must be adequate and should generally lie within a range of 2-4 m.

7.4.7 Marking for pedestrian crossing mostly used is the Zebra pattern consisting of equally spaced white stripes generally 500 mm wide in accordance with IRC: 35-1997.

7.4.8 At mid-block pedestrian crossing in urban areas, it may be advantageous to install flashing signals alongwith the markings, so that the drivers receive advance warning about the presence of the crossing.

7.5 Box Markings

7.5.1 Critical intersection areas are marked with yellow crossed diagonal lines in the form of a box to indicate the areas where vehicle must not become stationary even for a short while. Drivers are prohibited from entering such areas even if the signal light is green but the area cannot be crossed. This is to ensure that the junction is not choked in the even of heavy traffic. Typical box junction markings are shown in IRC:35-1997.

For further details and all other situations, specially for provisions in respect of continuity lines, cycle track crossings, makings on speed change lanes, Directional Arrows, Marking on Protected Right Turn Lanes, Marking at Rotaries etc. ,the detailed guidelines contained in IRC-35 shall be referredto and followed.

8.0 Markings for Parking

8.1 Parking Spaces

8.1.1 The marking of the parking space limits on urban roads promotes more efficient use of the parking spaces and tends to prevent encroachment on fire hydrant zones, bus stops, loading/unloading zones and other such locations where parking of vehicle will be undesirable. Such parking space limits should be indicated in the carriageway by typical markings as shown in IRC:35-1997. The markings shall be solid white lines 100 mm wide.

8.2.1 The limits of the designated parking places should also be indicated by informatory parking signs mounted on the kerb side in accordance with IRC:67-2012.

8.2 Marking indicating Parking Restrictions

Kerb or carriageway marking shall be used to show where parking is prohibited. The marking should be continuous yellow line 100 mm wide covering the top of the kerb or the carriageway close to it. The face of the kerb may also be painted similarly.

8.3 Bus Stops

8.3.1 Pavement markings at the bus stops should be provided with the word BUS STOP written prominently on the pavement in accordance with the provisions of

IRC:35-1997. Pedestrian crossings should be marked slightly behind the standing position of buses in order to avoid conflicts. Moreover, the kerbs should be marked with continuous yellow line to indicate no parking. This marking should be used only to supplement a road side bus stop sign and has no mandatory significance for drivers of other vehicles, unless yellow waiting restrictions marking is provided on kerbs.

8.3.2 The length of the bay for bus stops shall be 15 m at the minimum. It may be increased in stages of 2 m upto a maximum of 40 m. The word message "BUS STOP" should be repeated if the bay is over 30 m in length. The line marking for bay shall be whites and 100 mm wide. Typical markings are shown in IRC:35-1997.

9.0 Word Messages

Information to guide, warn or regulate traffic may also be conveyed by inscription of word message on road surface. Some of these augment kerbside signs, others indicate the areas of the carriageway intended for a particular function (e.g. Bus Stop) or meant to be kept clear (e.g. School).

In respect of word messages, the legends shall be as brief as possible and shall not contain more than three words for any message.

All these legends shall be in white and except on well-lighted roads shall be reflectorisedspecially where night-time visibility is restricted. The letters shall be elongated in the direction of traffic and at particular hazardous situations the markings may be repeated to give added emphasis.
All details like the height and spacing of the letter etc. shall be as per IRC-35-1997.

For all other situations and details, the detailed guidelines contained in IRC-35 shall bereferred to and followed.

10.0 Object Marking

10.1 Objects within Carriageway

For obvious reasons the objects within the carriageway are the most hazardous of all and at no time there shall be any slippage in the proper maintenance of the marking for such objects.
The obstruction in the carriageway shall be marked by not less than five alternate black and white stripes. The stripes shall slope at an angle of 45° towards the side of obstruction on which the traffic flows. The stripes shall be uniform and not less than 10 cm in width. These shall be wide enough to provide sufficient visibility depending on the size of the object and speed of approaching traffic.

10.2 Objects Outside The Carriageway But Adjacent to it

Technically these objects are not lying within the carriagewaybut nevertheless the highway engineer has to recognise the hazard potential of such closely lying objects to fast traffic and straying vehicles. It is, therefore, necessary that these objects are identified and marked clearly.
The object shall be marked with alternate black and white diagonal stripes sloping downward at an angle of 45° from the object towards the

carriageway carrying traffic.

All such adjacent objects or protrusions upto a distance of 1.5 metres outside the edge of formation shall be provided with the painting. Poles adjacent to the carriageway shall be marked with alternate black and white horizontal stripes upto a height of 1.25 metres above the level of carriageway. The stripes shall 'be of uniform width and not less than 10 cm wide. Other objects constituting solid obstructions such as drums, guard- rails etc. beyond 1.5 metres from the edge of formation which in normal circumstances may not hit unless the vehicle runs off the carriageway, shall be painted solid white upto a height of 1.25 metres above the carriageway level. In the case of trees there shall be a continuous black band of 30 cm width in the middle portion of the white area to make it more prominently visible.

10.3 Regarding highlighting the objects with hazard potential lying beyond a distance of 1.5 metres of the edge of formation the exercise of judgement and discretion by the highway engineer is most important, Even when some of these objects lie apparently at a respectable distance they may actually constitute a hazard. The traffic intensity at the location, nature oftraffic, average speed of passing vehicles and the past accident history of the location shall be the correct guidelines for identification of the need for marking.

10.4 For all details of kerb marking, marking of speed-breakers, humps etc. and placement of their cautionary signboards, the details indicated in IRC-35 shall be referred to and followed.

11 Reflective Pavement Markers (ROAD STUDS) and Solar Powered Road Markers (SOLAR STUDS)

Reflective pavement marker (RPM) or road stud is a device which is bonded to or anchored within the road surface, for lane marking and delineation for night-time visibility.

11.1 Material

11.1.1 Plastic body of RPM/road stud shall be moulded from ASA (Acrylic Styrene Acrylonitrite) or HIPS (Hi-impact Polystyrene) or Acrylonitrile Butadiene Styrene (ABS) or any other suitable material approved by the Engineer. The markers shall support a load of 13,635 kg tested in accordance with ASTM D 4280.

11.1.2 Reflective panels shall consist of number of lenses containing single or dual prismatic cubes capable of providing total internal reflection of the light entering the lens face. Lenses shall be moulded of methyl methecrylate conforming to ASTM D 788 or equivalent.

11.2 Design

The slope or retro-reflective surface shall preferably be 35± 5º to base and the area of each retro-reflective surface shall not be less than 13.0 sq.cm.

11.3 Optical Performance

11.3.1 Unidirectional and Bi-directional Studs

Each reflector or combination of reflectors on each face of the stud shall have a Coefficient of Luminous Intensity (C.I.L) not less than that given in Tables 5.1 or 5.2 as appropriate.

11.3.2 Omni-directional Studs

Each Omni-directional stud shall have a C.I.L. of not less than 2 mcd/Ix.

Table 5.1 : Minimum C.I.L. Values for Category 'A' Studs

Entrance Angle	Observation Angle	C.I.L. in mcd/Ix		
		White	Amber	Red
0º U 5º L&R	0.3º	220	110	44
0º U 10º L&R	0.5º	120	60	24

Table 5.2 : Minimum C.I.L. Values for Category 'B' Studs

Entrance Angle	Observation Angle	C.I.L. in mcd/Ix		
		White	Amber	Red
0º U 6º L&R	0.3º	20	70	4
0º U 10º L&R	0.5º	15	7.5	3

Note:

1) The entrance angle of 0º U corresponds to the normal aspect of the reflectors when the reflecting road stud is installed in horizontal road surface.
2) The stud incorporating one or more corner cube reflectors shall be included in Category 'A'. The stud incorporating one or more bi-connvex reflectors shall be included in Category 'B'.

11.4 Tests

11.4.1 Co-efficient of luminance intensity can be measured by procedure described in ASTM E 809 " Practice for Measuring Photometric Characteristic" or as recommended in BS:873-Part 4 : 1973.

11.4.2 Under test conditions, stud shall not be considered to fail the photometric requirements if the measured C.I.L. at any one position of measurement is less than the values specified in Tables 5.1 or 5.2 provided that

i) the values is not less than 80 percent of the specified minimum, and
ii) the average of the left and right measurements for the specific angle is greater than the specified minimum.

11.5 Solar Powered Road Markers (Solar Studs)

The solar studs shall be made of Aluminium alloy and poly carbonate material which shall be absolutely weather resistant and strong enough to support a load of 13,635, kg tested in accordance with ASTM D 4280. Its colour may be white, red, yellow, green or blue or combination as directed by the Engineer. Its water resistance shall meet the requirements of IP 65 in accordance with IS:12063:1987 Category 2 for protection against water ingress. The dimensions of solar studs shall not be less than 100 mm x 100 mm x 10 mm. It shall have super bright LEDs so as to provide long visibility from a distance of more than 800m . Its flashing rate shall not be less than 1 Hz. Its should be able to give the prescribed performance in the temperature range of -40ºC to +55ºC. Its life shall be note less than 3 years.

11.6 Fixing of Reflective Markers

11.6.1 Requirements

The enveloping profile of the head of the stud shall be smooth and the studs shall not present any sharp edges to traffic. The reflecting portions of the studs shall be free from crevices or ledges where dirt might accumulate. Marker height shall not be less than 10 mm and shall not exceed 20 mm and its width shall not exceed 130 mm. The base of the marker shall be flat within 1.3 mm. If the bottom of the marker is configured, the outermost faces of the configurations shall not deviate more than 1.3 mm from a flat surface. All road studs shall be legibly marked with the name, trade mark or other means of identification of the manufacturer.

11.6.2 Placement

The reflective marker shall be fixed to the road surface using the adhesives and the procedure recommended by the manufacturer. No nails shall be used to affix the marker so that they do not pose safety hazard on the roads. Regardless of the type of adhesive used, the markers shall not be fixed if the pavement is not surface dry and on new asphalt concrete surfacing until the surfacing has been opened to traffic for a period of not less than 14 hours. The portions of the highway surface, to which the marker is to be bonded by the adhesive, shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers, paint and any other material which would adversely affect the bond of the adhesive.

The adhesive shall be placed uniformly on the cleaned pavement surface or on the bottom of the of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker with no voids present and with a slight excess after the marker has been lightly pressed in place. For epoxy installations, excess adhesive around the edge of the marker, excess adhesive on the pavement and adhesive on the exposed surfaces of the markers shall be immediately removed.

11.6.3 Warranty and Durability

The contactor shall submit a two year warranty for satisfactory field performance including stipulated retro-reflectance of the reflecting panel, to the Engineer. In addition, a two year warranty for satisfactory infield performance of the finished road marker shall also be given by the contractor who carriers out the work of fixing or

reflective road markers. In case themarkers are displaced, get worn out or lose their reflectivity compared to stipulated standards, the contractor would be required to replace all such markers within 15 days of the intimation from the Engineer, at his own cost.

12. Specifications for Road" Marking Work

12.1 For carrying out actual work of road marking,the detailed specifications laid downby the Roads Wing of the Ministry of Surface Transport(Clause 803: Specifications for Road and Bridge Works) shall be followed.
For all details regarding marking work reference shall, therefore, be made to the above mentioned document. Some of the salient features of the marking work are mentioned below in brief for guidance.

12.2 Road Marking Paints

The paint for road marking are generally of following types.

(i) Ordinary road marking paint conforming to Grade I of IS:164..
(ii) Reflectorised paint as specified in the item of work.
(iii) Hot applied thermoplastic paints conforming to the requirements of AASHTO M-249 or relevant B.S. Specifications.
(iv) Cold Applied Reflective Paint.

12.2.1 Ordinary road marking paints are not very bright and lose their lustre soon. After being exposed to traffic for a time they fail to catch the driver's eye from a distance. It has, therefore, been suggested to use these paints only when conforming to IS:164-1981 with an additional proviso that these shall have a wear resistance of at least 4 hours under accelerated laboratory test.

12.2.2 Reflectorised Paint

12.2.2.1 To improve upon the performance of ordinary paints reflectorised paints are used. These paints, besides normal road marking ingredients contain special chemicals and materials like reflecting glass beads etc. Apart from reflection of incident light to catch the eye of the driver at night these paints also have longer road life than ordinary paints. Two types of glass beads may be used for the production of reflectorised pavement markings.

12.2.2.2 Type 1 beads are the same as specified in paragraph 12.2.2.3 of the basic constituent of the thermoplastic compound and type 2 beads shall in addition conform in quality to the beads used for spraying on the road surface (Para 12.3.4)

12.2.2.3 The glass beads shall be transparent, colourless and free from milkiness, dark particles and excessive air inclusions. In gradation the beads shall conform to the following table.

Table 5.3.GRADATION REQUIREMENT OF GLASS BEADS

Sieve Size	Percent Retained	
	Type 1	**Type 2**
1.18 mm	0 to 3	
850 micron	5 to 20	0 to 5
600 micron	----	5 to 20
425 micron	65 to 95	----
300 micron	----	30 to 75
180 micron	0-10	10 to 30
Below 180 micron	----	0 to 15

12.2.2.4 Properties of glass beads

(a) Gradation : The glass beads shall meet the gradation requirements for the two types as given in Table 5.3

(b) Roundness - The glass beads must have a minimum of 70 percent spheres.

(c) Refractive Index - The glass beads shall have a minimum refractive index of 1.5.
(d) Free flowing properties - The glass beads shall be free of hard lumps and clusters and shall dispense readily under any conditions suitable for paint striping. They shall pass the free flow test.
The requirements of gradation, roundness and refractive index of the glass beads and the amount of glass beads in the compound shall be tested as per BS-6088 and BS-3262 (Part I). The free flow test shall be carried out as described in clause 803 of the Ministry of Surface Transport Specifications.

12.2:3 Thermoplastic Paint

12.2.3.1Requirements
The aggregates, beads and pigment shall be in a uniform and homogenously mixed condition in the resin. The material shall be free from dirt, skins and foreign objects..The composition shall comply with the requirements as given in Table 5.4

Table 5.4 : Proportions of Constituents of Marking Material (Percentage by Weight)

Component	**White**	**Yellow**
Binder	18.0 min.	18.0 min.
Glass Beads	30-30	30-30
Titanium Dioxide	10.0 min.	----
Calcium Carbonate and Inert Fillers	42.0 max.	See note below
Yellow Pigments	----	See note below

Note: Amount of yellow pigment, calcium carbonate and inert fillers shall be as prescribed by the manufacturers provided the mix meet all other requirements of the specifications.

12.2.3.2 Other properties of the thermoplastic materials when tested in accordance with ASTM D-36 or BS-3262 (Part I) shall be as below.

(a) Luminance: White :Daylight luminance at 45° -65% minimum as per AASHTO M- 249.
Yellow : Daylight luminance at 45° -45% minimum as per AASHTO M-249.

(b) Drying Time :When applied at a temperature specified by the manufacturer and tothe required thickness, the material shall set to bear the traffic in not morethan 15 minutes.

(c) Skid Resistance :Not less than 45 as per BS: 6044.

(d) Cracking Resistance at low temperature :The material shall show no cracks on application to concrete blocks.

(e) Softening Point : 102.5 ± 9.5°C as per ASTM D36.

(f) Yellowness Index (for white thermoplastic paint) :Not more than 0.12 as per AASHTO M 249.

12.2.3.3 Storage Life

The material shall meet the requirements of these specifications fora period of one year. The thermoplastic material must also melt uniformly with no evidence of skins or unmelted particles for the one year storage period.

12.2.3.4 Reflectorizing Glass Beads

Reflectorisation shall be achieved by incorporation of beads. The grading and other properties of the beads shall be as indicated in Para 12.2.2.3.

12.2.4 Cold Applied Reflective Paint

This consist of marking traffic stripes using a solvent based cold applied paint, which shall be applied on the asphalt/cement concrete road surface by brush or by Road Marker (Spray equipment capable of spraying the paint on the road). Glass beads shall be subsequently spread pneumatically on to the paint when it is still wet so that the beads will be firmly held by the paint after frying. Colour of the paint shall be white or yellow.

The properties and application of Cold Applied Reflective Paint are described in clause 803.7 of the Ministry of Surface Transport Specifications, which may be referred to.

12.3 Application

12.3.1 The road surface to be provided with the markings shall be clean, dryand free from grease, oil, dirt or loose material. A cleaning method finallyending in cleaning by compressed air or fine bristled broom shall be preferred. Any pre-treatment, primer or adhesive binder, if prescribed by the manufacturer of the paint, shall be applied to the surface before painting. Where the compound is to be applied to cement concrete pavement, a sealing primer shall be applied to the pavement in advance of placing of the stripes to ensure proper bonding of the compound.

12.3.2 Wherever possible painting work shall be carried out by (approved) equipment. The equipment shall preferably be capable of at least

(i) Painting two parallel lines of 10 cm width, with a gap of 10 cm in between, in continuous or intermittent pattern and in various combinations of the above so as to be able to paint most of the common road markings,

(ii) It should be able to automatically spread glass beads on the painted surface at various controllable rates by pressurized glass-guns or similar approved method and

(iii) It shall preferably contain a device to automatically record the total length of lines so painted to the nearest 0.5 metre.

For curved letterings and complicated patterns, where machine painting may not be possible, manual painting· may be done with the approval of the Engineer.

12.3.3 The thermoplastic material shall be applied hot either by screeding or by extrusion process. The material shall be laid at a temperature within the range specified by the manufacturer for the particular method of laying being used.
The temperature of the pavement shall not be less than 10^0C during application.

12.3.4 The material, when formed into markings, must be capable of being renewed by placing an overlay of new material on old line so as to form proper bond. The thickness of the paint in the marking shall be uniform and at least 2.5 mm (exclusive of top glass bead spread) unless specified otherwise.
In addition to the beads incorporated in the paint (for thermoplastic paints) a further quantity of glass beads of Type-2 as specified in para12.2.2.3shall be spread at the rate of 250 gm per square metre in a single layer on the top of the hot paint.

12.3.5 Where the existing lines/patterns are visible and confirmed to be at the correct location, repainting on existing markings may be done after cleaning the surface properly. Where the markings are not correctly located the same shall be fully removed, the correct location determined accurately and the same shall be painted as per specifications. Painted lines/patterns not found to be within 10 cms of correct location shall. be fully removed and repainted at the correct location as per specifications.

12.4 Protection of painted surface

Adequate road signs, safety barriers and cones shall be placed around the area where painting operation is in progress upto a minimum period of 30minutesafter painting or upto the time when the painting is completely dry, whichever is more, and the work shall be commenced only after alternative arrangement for diversion of traffic has been made. Any smearing or damage to the painting after opening to traffic shall be removed and the affected length repainted.

As far as possible, painting work shall be done during a time when the traffic volume on the road is the least.

12.5 Storage and handling of materials

The paint material shall have an adequate storage life and the test properties prescribed shall hold good for a period of at least one year in storage. All paint drums stored for more than two months shall be kept in an inverted position for seven days before being opened for actual use.

The glass beads shall be stored in a dry and cool place.

13.0 Maintenance of road markings

13.1. All road markings require to be maintained in an effective condition at all times. Due.to action of weather, aging and wearing due to traffic they undergo deterioration with passage of time. Some broad thumb-rules regarding the periodicity of re-painting may be as below:-

- Ordinary road paint markings may last for a period of 6 months or so and may need re-painting after that.
- Ordinary grade reflector zed paint may last for a period of one year or so.
- The life of thermoplastic paint may be taken as two to three years on a busy road.
- Iron, wood and concrete posts may be painted regularly and preferably once in a year.

13.2. For carrying out routine maintenance and repainting work the following points require to be kept in mind.

- Before repainting traces and remnants of old and obsolete markings which are sufficiently visible to cause confusion shall be removed.
- Reflector units shall be scrubbed and cleaned periodically specially after the rains.
- The ground around delineators shall be kept clean by cutting grass and removing unwanted wild growth-at least once every 3 months or so at ordinary times and at least once in a month during rainy season.

13.3. Removal of old and obsolete pavement marking

13.3.1 Traces of old and obsolete pavement marking, where existing, shall be removed by an approved method. Painting in black over the existing markings is not considered an acceptable method. It has to be ensured that the removal method shall cause the least damage to the pavement structure and surface.

13.3.2 The agency for carrying out the work shall furnish in detail the procedure to be adopted for removal, safety precautions to be taken during the work, time and duration of the work and satisfactory repair method for any damage caused during removal. The work shall commence only after the approval of the procedure by the Engineer-in-charge.

14.0 Sketches of Road Markings

The road marking symbols, patterns and legends as adopted are described in detail in IRC-35-1997 and the same shall be followed. A set of sketches of the important symbols/patterns is enclosed to this note for recapitulation.

Summary of markings showing the types, colour and sizes of various markings used in IRC:35-1997 is placed at Appendix-II

15.0 General practice in PWD Delhi, UTTIPEC & Drawings.

REFERENCES

1. Code of Practice for Road Markings (with paint)- IRC:35-1997.
2. Specifications for Road and Bridge Works - Ministry of Surface Transport (Roads Wing).
3. Highway Engineering- V.F. Babkov.
4. Specifications - Department of Transportation, Commonwealth of Pennsylvania.

S. No.	Description	Location	Colour	Details of Markings Type	Width cm	Length of line segment m	Length of gap m
1	2	3	4	5	6	7	8
1.	Centre Line	(a) Rural (i)Straight reaches -NH/SH -Others	 White White	 Broken single -do-	 10 10	 3.0 3.0	 6.0 4.5
		(ii) Curves and approaches to inter-sections. -NH/SH -Others	 White White	 -do- -do-	 10 10	 3.0 3.0	 3.0 3.0
		(b) Urban (i) Less than 4 lanes -Straight reaches -Curves and approaches to inter-sections	 White White	 -do- -do-	 15 15	 3.0 3.0	 4.5 3.0
		(ii) Four lanes or more undivided	White (optionally yellow)	Solid single or double	15 10+10	- -	- -
2.	Traffic lane line	(a) Rural (i) Straight reaches	White	Broken single	10	3	6
		(ii) Curves and approaches to intersections	White	Broken single (Exceptionally solid) refer Para 8.3.4	10	3	3
		(b) Urban					
		(i) Straight reaches	White	As above	10	1.5	3
		(ii) Curves and approaches to	White	As above	10	1.5	1.5

		intersections					
3.	No overtaking zone		Yellow	Solid single or Solid double or Solid and broken	10	As for centre line	
4.	Warning line	All locations	White	Broken single	Equal to the normal preceding lines	Lengths of the lines segments and gaps or normal lines are interchanged. Minimum seven line segments at each location	
5.	Border or Edge line	All locations	White	Solid	15 or 20	-	-
6.	Bus lane	All locations	White	Solid	25	-	-
7.	Bicycle lane	All locations	White	Solid	15	-	-
8.	Stop line	(a) Rural	White	Transverse solid single or double	- 30 or 20+20	-	-
		(b) Urban	-do-	-do-	20 or 20+20	-	-
9.	Give way lines	All locations	White	Transverse broken	20+20	0.60	0.30
10.	Continuity lines	(a) Centre line & lane lines	White	Transverse broken	As an approaches to intersections		
		(b) Median and Island line	White	Broken single	10	0.60	0.30
11.		(c) Stop line and give way line	White	Transverse broken single	10	0.60	0.30
		(d) Turn markings	White	Broken Single	10	0.50	0.50
1.	Pedestrian crossing	All locations	White	Zebra Stripes	50 cm wide stripes 50 cm apart 2 m to 4 m long		
2.	Cycle Track crossings	All locations	White	Solid	10 cm		
3.	Speed change	All locations	White	Solid lines with diagonals/	60 cm wide diagonals/chevrons 15 cm wide lines		

				chevrons			
4.	Directional arrows	All locations	White	Arrows	3.5 cm or 5 m long		
5.	Protected right	All locations	Yellow	Diagonals enclosed by solid lines	15 Size variable as per site conditions		
6.	Markings at rotaries	All locations	White/Yellow	Broken/solid	Size variable as per site conditions		
7.	Box marking	All locations	Yellow	Crossed diagonals enclosed by solid lines	10	Size variable as per site conditions	
8.	Carriageway Width Transaction	All locations	White	Solid single	15	-	
9.	Obstruction Approach Marking	All locations	Yellow	Diagonals/ Chevrons enclosed by solid lines	15	-	
10.	Road Rail level crossing	All locations	White/ Yellow	Combination of stop line, Centre line and lane lines	-	-	
11.	Parking Spaces	All locations	White	Broken	10/5	-	-
12.	Parking Restrictions	All locations	Yellow	Solid	10	-	-
13.	Bus Stops	All locations	White	Broken	10	1m	1m
14.	Word Messages	All locations	White	Alphabets, numerals and aporstophe-size as per Plates II and III.			
15.	Object Markings	All locations	Black and White or Black and Yellow	Alternative stripes widths varying for different usages			
16.	Speed Breakers	All locations	White	Elongated Triangles			

CHAPTER -6
ROAD DELINEATORS AND SAFETY BARRIERS

1.0 Introduction

1.1 Road delineators are devices or treatments for the purpose of prominently outlining the roadwayor portion thereof or any other object or point of hazard. Essentially, these are visual guides/confirmatory signs regarding the actual configuration of the alignment in front of the road user. These may include painted lines, pavement marker posts, post-mounted reflectors etc. According to their specific functions they may be classified as below:-

(i) Road Indicators
(ii)Hazard Markers and
(iii) Object Markers

1.2 The delineators shall conform to 'the Recommended Practice for road delineators' (IRC-79-1981) published by the Indian Roads Congress which shall be referred for all details. The criteria for use of delineators, their spacing, placement and design shall, in, general be as indicated in it. Some salient features of the same are quoted in the following paragraphs.

2.0 Road Indicators

2.1 Generally the road way indicators shall be in the form of guide-posts made of metal, concrete, timber, plastic etc. They will have height of 80cm to 100cm above the ground and shall be painted alternately in black and whitestripes with 15 cm width. Plastic posts are light and present less hazards tovehicles which have deviated from their course. They, however, run the risk of being pilfered.

2.2 The posts may be circular, rectangular or triangular in cross-section but must present a width of at least 10cm towards the traffic side. These may be with or without reflectors but delineators with reflectors are preferred. The reflectors may be either circular or rectangular (sometimes empty bitumen drums have also been used as delineators).

2.3 In general, the road indicators are mostly used in complex locations involving changes in horizontal/vertical geometry. Horizontal curves of radius 1000 metre or less and vertical curves with inadequate visibility and straight road sections with road embankment exceeding 3 metres in height, approaches to narrow bridges and culverts and pavements with transition or temporary diversion require their provision.

2.4 In general, the delineator posts shall be erected at the edge of the shoulder and in the case of the kerbed sections at a distance of 0.6 to 1.5 m from the kerb face.

The overall line of posts shall be parallel to the centre-line of the road except at guard-rails or other obstructions where the delineators may be in line with or inside the innermost edge of the obstruction.

On straight sections the indicators shall be spaced uniformly at 50 to 70 metre from each other, the posts being in pair with one on each side of the roadway. On divided highways these should also be provided on the medians.

The spacing on horizontal and vertical curves shall be as indicated in clause 3.11 and 3.12 of IRC:79-1981.

3.0 Hazard Markers

3.1 Generally, hazard markers are installed when there are objects too close to the road so as to be a potential hazard. These are available in two typical designs of rectangular shape. The first type consists of a thin vertical board of 20 cm width and 60 cm height (excluding the mounting post), with three circular reflectors of 10 to 15 cm diameter arranged in a vertical row. The other alternative type consists of rectangular boards 30cm (width) by 90cm (height) with black and yellow sloping stripes 10cm apart.

3.2 The marker shall be put up wherever there are objects too close to road to be an accident hazard like bridge abutments, guard rails etc.

The markers should be erected immediately ahead of the line of obstruction and the inside edge of the marker should be in line with the inner edge of the obstruction as far as possible.

4.0 Object Markers

4.1 The object marker will generally be triangular in shape but may be - rectangular also. There are a few alternative designs like triangular all red reflector board with white border or white background board containing red reflectors with red border on the board etc.

4.2 The markers should be erected facing the traffic close to the point where the obstruction within the roadway starts, for instance in the case of a channelizingisland at its nose-point.

The height of the object market may vary but shall, generally, be 40 to 50 cm so that the reflectors are fully visible to the approaching traffic.

5.0 Calming Measwals (SCM).

Speed calming&rumble strips for the purpose of controlling the approach speeds of vehicle should be provided in consultation with the local traffic police. Detailed guidelines for Speed breaker is given inlRC:99-1988 and may be followed. On national highways, to the extent possible, in the interest of unimpeded traffic flow and road safety, speed breaker should be avoided. But wherever they cannot be avoided due to public resistance or prevailing site conditions (e.g. near railway crossing or an approach to narrow/ weak bridge) then the same should be replaced by rumbling strips. Rumbling strips are raised section of premixed carpet or bituminous surface dressing of 15-25mm high, 200-300mm wide and space about 1 m centre to centre and are to be laid in a series of 15-20 strips at one location. They are effective in reducing approach speed by combination of vibration and rumbling noise. Speed breaker or rumbling strips wherever provided shall be marked with thermoplastic paint and planted by warning/speed limit signs on approaches (D.O.No. RW/NH-11064/91-DO1 Dt. 10.02.1993).

6.0 Road Safety Barriers:

In urban areas where there is restricted space for median, a vehicle crossing across the median of dual carriageway runs the risk of colliding with oncoming vehicle from opposite direction or road in high embarkment, sharp curves, hazardous obstacles such as poles trees etc. are all requires some kind of protective barriers such that severity of accident due to striking against barrier is less than what it will be without the barrier. Safety barriers therefore absorbs impart energy and reduces severity of accident involving vehicles leaving the travelled way. Decision

regarding installing safety barriers is governed by safety and structural requirements duly considering social, economical& environmental factors. Detailed guidelines about the type of safety barrier, their warrants, layout and fixing details are circulated by MOST vide circular no. RW/NH-33022/1/94-DO111 Dt. 24.6.1994 and may be followed. A few of road safety barrier are shown in IRC:79-1981.

7.0. The design and dimensions of the different types of markers shall conform to the standards laid down in IRC:79-1981. A few sketches of some of the common markers are furnished in the Appendix to this note.

8.0. Reflectors can be made of films, synthetic materials like plastic or glass. Whatever material is used, it should have stable optical characteristics, the prescribed colour and a visibility of at least 200 metres under clear weather conditions when illuminated by the upper beam of the car headlights.

8.1. For specifications for carrying out the work the provisions of clause 806of the Specification for Road and Bridge Works of the Ministry of Surface Transport may be followed.

REFERENCES

1. Recommended Practice for Road Delineators - IRC:79-1981.
2. Specifications for Road and Bridge Works - Ministry of Surface Transport (Roads Wing).

CHAPTER·7
ROAD SIGNS

1.0 Introduction

To ensure smooth and efficient flow of traffic, to reduce the area of conflict and prevent accidents and adjust and regulate the needs of the traffic to the capacity and the limitation of the facility under use, the road requires to bein constant communications with the road user. The road signs (along with the road markings) constitute the language in which the road speaks to the road user.

1.1 Purpose of Road Signs

The purpose of road signs is to promote road safety and efficiency by providing for the orderly movement of all road users on all roads in both urban and non-urban areas. Road signs notify road users of regulations and provide warning and guidance needed for safe, uniform and efficient operation.

1.2 Principles of Road Signs

To be effective, a road sign should meet five basic requirements:

a) Fulfill a need ;
b) Command attention ;
c) Convey a clear and simple meaning ;
d) Command respect from road users ; and
e) Give adequate time for response.

Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a road sign to meet these five basic requirements.

1.3 Placement and Operation of Road Sign

Placement of road signs should be within road user's view. To aid in conveying proper meaning, road signs should be positioned with respect to the location or situation to which it applies. The location and legibility of the road sign should be such as to provide adequate response time to road users to read and take action at the operating speed. Road signs or their supports shall not bear any advertising or other message that is not related to traffic control.

1.4 Maintenance of Road Signs

Maintenance of road signs should be ensured to retain both the legibility and the visibility of the sign. Functional evaluation of road signs should be done to determine at regular periodic intervals, whether certain signs need to be changed to meet current traffic conditions. Clean, legible, properly mounted signs in good working condition command respect from road users.

1.5 Uniformity of Road Signs

Uniformity of signs simplifies the task of the road user because it helps in recognition and understanding, thereby reducing perception/reaction time. Uniformity assists road users, traffic police and highway agencies by giving everyone the same interpretation message. Uniformity also promotes efficiency in manufacture, installation and maintenance.

1.6 General Guidelines for signs on Urban & City Roads

The signing system for urban and city roads should help road user to get clear and unambiguous information where there could be many advertisement hoardings and road

side activities. The Vulnerable Road Users like pedestrians and cyclists and signs for disabled people would play important role in urban and city road signing.

Signs are designed so that they are legible to road users approaching them and can be read in time to permit proper responses. Desired design characteristics include: (a) long visibility distances, (b) large lettering and symbols, and (c) short legends for quick comprehension.

2.0 Classification of Road Signs

A broad classification is made in the light of the message the sign intends to convey and these may be of three types:-

i) Mandatory/Regulatory Signs,
ii) CautionarylWarningSigns and
iii) Informatory/Guide Signs

2.1. Mandatory/Regulatory

These signs remind the road user about the existing laws and regulations to which the road user is subject and is bound by law to follow. It may also inform the road user about special obligations and restrictions which the road user must comply to and prohibitory orders that may be in force against certain categories of vehicles on certain roads or during certain specified periods of time. Violation of these signs is a legal offence. A complete list of the mandatory/regulatory signs is given in Appendix-I to this chapter. Broadly they will fall under the following groups:-

(a) ‘Stop' and 'Give Way' signs (Right of way signs)
(b) 'Prohibitory' signs,
(c) 'No Parking' and 'No Stopping' signs,
(d) 'Speed Limit' and 'Vehicle Control' signs,
(e) 'Restriction Ends' signs and
(f) 'CompulsoryDirection Control' and other signs.

2.2 Cautionaryl Warning Signs

These signs caution and alert the road usersto potential danger or existence ofcertain hazardous conditions either on or adjacent to the roadway so that they take the desired action. These signs indicate a need for special caution by road users and may require a reduction in speed or some other manoeuvre.

The presence of sharp curves, rough or damaged roads, narrow or weak bridges, presence of school requiring driving with greater care and circumspection etc. may form the substance of the cautionarylwarning sign messages. A complete list of cautionarylwarning signs is given in Appendix I to this chapter. .

2.3 Informatory/Guide Signs

These signs provide useful information and guidance to the road user and keep him posted with tips regarding places of historical/geographical interest along the road and also about the route, distance to different destinations etc. So far as urban situations are concerned,these signs maybe grouped as under:-

(a) Directionand Place Identification signs,
(b) Facilitylnformation signs,
(c) Other useful Information signs,

(d) Parking Signs. And
(e) Flood Gauge

A complete list of informatory signs is given in Appendix I to this chapter.

3.0 Standard Features

For use in this country the shape and size of the road signs, the size of the legends and letterings, their colour, configuration and location shall be guided by the following publications brought out by the Indian Roads Congress.

IRC-67-2012- Code of Practice for Road Signs (Third Revision)
IRC-SP-31-1992- New Traffic Signs (Under Revision)

Some of the salient features mentioned in the codes are quoted below but for detailed guidance regarding provisions the IRC Publications mentionedabove shall always be referred to and followed.

3.1 Shape

The general shape of the mandatory/regulatory signs is circular except for Octagonal red STOP sign and the triangular GIVE WAY or YIELD sign. These two signs provide indication about right of way to drivers.

Similarly, the general shape of the cautionary/warning signs shall be equilateral triangles with the apex pointing upwards.

The informatory and guiding signs are rectangular in shape .

3.2 Size

In general, there shall be four sizes (small, medium, normal and large) of signs for mandatory/regulatory and cautionary/warning signs. The size of signs generally depend upon the speed of vehicle permitted on that corridor. On expressways the size of the signs may be bigger than the normal size depending upon the design speed.

For actual manufacture of the signs, the detailed drawings and specifications of IRC-67- 2012 shall be followed. In brief, for general guidance some details are as below:

Table 7.1 Sizes and Dimensions of 'STOP' signs

Approach speed on minor road	Size	Height (mm)	Border (mm)	Font Size (mm)
Up to 50 kmph	Small	750	25	125
51-65 kmph	Normal	900	30	150
65 kmph	Large	1200	40	225

Table 7.2 Size and Dimension of Give Way Sign

Approach speed on minor road	Size	Side (mm)	Border (mm)
Up to 50 kmph	Small	600	45
51-80 kmph	Normal	900	70
80 kmph	Large	1200	90

Table 7.3 Size and Dimension of Mandatory and Regulatory signs

Design Speed	Size	Regulatory Signs	Mandatory Signs			
		Diameter (mm)	Diameter (mm)	Border (mm)	Oblique Bar (mm)	Font Size (mm)
Up to 65 kmph	In conjunction with traffic light signal		300	35	35	75
	Small	600	600	50	50	100
66-80 kmph	Medium	750	750	60	60	125
81-100 kmph	Normal	900	900	75	75	150
>100 kmph	Large	1200	1200	100	100	225

Table 7.4The Sizes and Dimensions of Cautionary Signs

Design speed	Size	Side (mm)	Border (mm)
Up to 50 kmph	Small	600	45
51-65 kmph	Medium	750	60
66-80 kmph	Normal	900	70
>80 kmph	Large	1200	90

Table 7.5 Letter Size and Siting of Information Signs (Shoulder & Gantry Mounted)

	Advance Direction Signs (Shoulder Mounted)					Flag Type Direction Signs Reassurance Signs Place Identification Signs			Gantry Mounted Signs		
1	2	3	4	5	6	7	8	9	10	11	12
Design Speed	"X" height (mm) lower case	"X" height (mm) upper case	Minimum clear visibility to the sign (m)	ONE sign: distance from junction (m)	TWO signs: distance between 1st and 2nd sign (m)	"X" height (mm) lower case	"X" height (mm) upper case	Minimum clear visibility to the sign (m)	"X" height (mm) lower case	"X" height (mm) upper case	Minimum clear visibility to the sign (m)
Up to 30 km/h	75 (60) *	105 (84)	50 (35)	20	-	60 (50)	84 (70)	35 (30)			
31-50	100	140	75	45	45	75	105	45			

km/h	(75)	(105)	(45)			(60)	(84)	(35)	200 (175)	280 (245)	150
51-65 km/h	125 (100)	175 (140)	100 (60)	90	50	10 (75)	140 (105)	60 (45)			
66-80 km/h	150 (125)	210 (175)	135	90-150	70	125 (100)	175 (140)	75 (60)			
81-100 km/h	200 (150)	280 (210)	165	150-225	100	150 (125)	210 (175)	105 (75)	250 (200)	350 (280)	200
101-110 km/h	250 (200)	350 (280)	225	225-300, See also Note 1	100	200 (150)	280 (210)	135 (105)	275 (250)	385 (350)	240
111-120 km/h	300 (250)	420 (350)	260	See Note 1	See Note 1	300 (250)	420 (350)	180 (150)	300 (275)	420 (385)	260
***Note : The values in brackets are the minimum values to be adopted when there are site/space constraints.**											

Notes:

1) For grade separated junction two or three advanced direction signs are provided. These are located at the start of diverging lane, 250 m to 750 m from the junction and additionally 750 m to 1500 m from the junction.

2) The “x” height is the height of a lower case English “Transport medium” font and upper case shall be 1.4 times of lower case height.

3) In columns 2,3,7,8,10 and 11 of Table 11.1 the font heights shown are normal size to be used for respective approach speeds and in brackets are the absolute minimum sizes to be used where site/space is limited. The font size can be increased by another 50 mm from the normal font size for those direction boards requiring special emphasis/attention.

3.3 Colour for Signs

Signs shall be provided with retro-reflective sheeting and/or overlay film as shown on the detailed drawings prepared based on guidelines prescribed in IRC: 67 -2012.

3.3.1 The colour of the material shall be located within the area defined by the chromaticity coordinated in **Table 7.6** and comply with the luminance factor given in **Table 7.7** when measured as per ASTM D: 4956-09. Chromaticity is the objective specification of the quality of a colour regardless of its luminance, that is, as determined by its hue and colourfulness (or saturation/chroma, or intensity)

Table 7.6 Chromaticity Coordinates (Daytime) [A]

Colour	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
White	0.303	0.300	0.368	0.366	0.340	0.393	0.274	0.329
Yellow	0.498	0.412	0.557	0.442	0.479	0.520	0.438	0.472
Green [B]	0.026	0.399	0.166	0.364	0.286	0.446	0.207	0.771
Red	0.648	0.351	0.735	0.265	0.629	0.281	0.565	0.346
Blue [B]	0.140	0.035	0.244	0.210	0.190	0.255	0.065	0.216
Orange	0.558	0.352	0.636	0.364	0.570	0.429	0.506	0.404
Brown	0.430	0.340	0.610	0.390	0.550	0.450	0.430	0.390
Fluorescent Yellow-Green	0.387	0.610	0.369	0.546	0.428	0.496	0.460	0.540
Fluorescent Yellow	0.479	0.520	0.446	0.483	0.512	0.421	0.557	0.442
Fluorescent Orange	0.583	0.416	0.535	0.400	0.595	0.351	0.645	0.355

A The four pairs of chromaticity coordinates determine the acceptable colour in terms of the CIE 1931 Standard Colourimetric System measured with CIE Standard llluminant D65.

B The saturation limit of green and blue may extend to the border of the CIE chromaticity locus for spectral colours.

Table 7.7Daytime Luminance Factor (Y%)

Colour	Non-Metallic Portion		Metallic Portion	
	Min	Max	Min	Max
White	27	--	15	--
Yellow	15	45	12	30
Green	3.0	12	2.5	11
Red	2.5	15	2.5	11
Blue	1.0	10	1.0	10
Orange	10	30	7.0	25
Brown	1.0	9.0	1.0	9.0
Fluorescent Yellow-Green	60	--	--	--
Fluorescent Yellow	40	--	--	--
Fluorescent Orange	20	--	--	--

The colours shall be durable and uniform in acceptable hue when viewed in day light or under normal headlights at night.

3.3.2 Stop Sign shall have red background and white border. The word “STOP” shall be written in white. GIVE WAY Sign shall have red border and white background. The word “GIVE WAY” shall be written in black.

"No Stopping" and "No Standing" Signs shall be with red border and blue background.

Compulsory Direction Control and Other Signs shall be with blue background and white border, and having symbols in white.

The Regulatory/Prohibitory and warning signs shall be provided with white background and red border. The legend/symbol for these signs shall be in black colour. The Mandatory Sign shall be provided with Blue background and white Symbol/letter. .

3.3.3 Colour pattern for direction information signs is given in Table 7.8

The Colours chosen for informatory or guide signs shall be distinct for different categories of roads. For various categories of road in India, following colour pattern shall be used for direction information sign as given in Table 7.8

Table 7.8 Colour Pattern for Direction Information Signs

Road Type	Background	Arrows/Border/Letters
Expressway	Blue	White
National Highway (NH)	Green	White
State Highway	Green	White
Major District Road (MDR)	Green	White
Village Road (ODR & VR)	White	Black
Urban/City Road	Blue	White

3.3.4 The sign posts shall be painted in 25 cm wide bands (except in case of level crossings) alternately black and white. The lowest band next to the ground shall be black.

For the level crossings the posts shall have one or two red bands (depending on distance of installation) conforming to the drawing shown in detail in IRC-67-2012.

3.4 Siting of Signs with respect to the carriageway.

The road signs are the means of communication to the road users, especially drivers. Therefore, the signs shall be so placed that the drivers can recognize them easily and in time. Normally the signs shall be placed on the left hand side of the road. For two lane roads, normally the signs may be placed on the left side of the carriageway, repeated on the other side of the carriageway, if local conditions are such that the signs might not be seen in time by the drivers. For multilane divided roads the signs may be placed on left side of each carriageway.

Where in the opinion of the competent authority, a sign would be ineffective if placed on the left hand side shoulder of a road with dual carriageway, it may be placed on the median instead.

The Signs shall be so placed that these do not obstruct vehicular traffic on the carriageway, and if placed on the berm/footpath/refuge island cause least obstruction to pedestrians.

On multi-lane roads, the signs may have to be mounted overhead, as this would ensure better visibility and be effective in communicating with drivers and other road users. Overhead signs may be used in lieu of , or as an adjunct to, ground signs where the situation so warrants for proper information and guidance of the road user.

From safety and aesthetic standpoints, overhead signs shall be mounted on overhead bridge structures wherever possible. Overhead signs shall provide a vertical clearance of not less than 5.5 m over the entire width of the pavement and shoulders.

3.4.1 Overhead Signs

Overhead signs shall provide a vertical clearance of not less than 5.5 m over the entire width of the pavement and shoulders except where a lesser vertical clearance is used for the design of other structures. The vertical clearance to overhead sign structures or supports need not be greater than 300 mm in excess of the minimum clearance of other structures.

The minimum clearance outside the usable roadway shoulders for signs mounted at the road side or for overhead sign supports either to the right or left side of the roadway shall be 1.80 m. This minimum clearance of 1.80 m shall also apply outside of an unmountable kerb. Where practicable, a sign should not be less than 3 m from the edge of the nearest traffic lane. Large guide signs should be farther removed preferably 9 m or more from the nearest traffic lane, unless otherwise specified. Lesser clearance, but not generally less than 1.80 m, may be used on connecting roadways or ramps at inter-changes.

Where a median is 3.6 m or less in width, consideration should be given to spanning over both roadways without a central support. Where overhead sign supports cannot be placed at a safe distance away from the line of traffic or in an otherwise protected site, they should either be so designed as to minimize the impact forces or protect motorists adequately by a physical barrier or guard rail of suitable design.

3.5 Orientation of Signs

The Signs shall normally be placed at right angles to the line of travel of the approaching traffic. Signs relating to parking, however, should be fixed at an angle (approximately) 15^0 to the carriageway so as to give better visibility.

On horizontal curves, the sign may not be fixed normal to the carriageway but the angle of placement may be suitably modified for increased visibility to the approaching traffic. Also, where lightreflection from the sign face is encountered to such an extent as to reduce legibility, the sign should be turned slightly away from the road.

Sign faces are normally vertical, but on gradients it may be desirable to tilt a sign forward or backward from the vertical to make it normal to the line of sight and improve the viewing angle.

3.6 Location

3.6.1 The 'stop' signs should be sited as close to the stop line as possible but not in such a position as to impair visibility along the major road. Normally these should be fixed 1.5m in advance of the stop line.If the site conditions prevent a sign soplaced from being easily seen, it may be placed at a greater distance inadvance of the line but not more than 6 metres from it.

3.6.2 Similarly, the 'Give Way' sign shall be located as near to the point where the vehicles are required to stop to yield the right-of-way as possible. A distance of 1.5 m to 12 m may be alright. It is also recommended that Give Way Line should be marked at the entry to junction.Give Way line may be preceded by GIVE WAY marking on the road. On gradients, the sign shall be placed at the start of the down gradient and repeated as necessary.

3.6.3 The 'Speed Limit' and 'Vehicle Control' signs shall be erected at the beginning of any section of a road or the side of a structure, which is subject to prohibition or restriction so as to face the entering traffic. Additional signs shall be erected within the prohibited zone at each intersection made by a road which is not subject to prohibition so as to inform the entering traffic about the restriction. For speed limit, additional repeater signs may be installed at suitable intervals wherenecessary.

3.6.4 The warning signs should normally be located depending upon 85th percentile speed of private cars (as detailed below in Table 7.10) in advance of the hazard warned against.

Table 7.10 : Siting Distance of Cautionery/Warning Signs

Design speed	Clear Visibility Distances (m)	Distance of sign from hazard (m)
Up to 50 kmph	45	45
51-65 kmph	60	45 - 110
66-80 kmph	60	110 - 180
>80 kmph	90	180 - 245

4.0 Materials for Signs

The various materials and fabrication of road signs shall conform to the following requirements:

4.1 Concrete: Concrete shall be of M25 grade.

4.2 Reinforcing Steel: Reinforcing steel shall conform to the requirements of IS 1786 unless otherwise specified.

4.3 Bolts, Nuts and Washers: High strength bolts shall conform to IS 1367 whereas precision bolts, nuts, etc. shall conform to IS 1364.

4.4 Plates and Supports: Plates and support sections for the signpost shall conform to IS 226 and IS 2062 or any other stated IS specification.

4.5 Substrate: The substrate shall be either Aluminium sheeting or Aluminium Composite Material (ACM) conforming to following sub-sections.

4.5.1 Aluminium

Aluminium sheets used for sign boards shall be of smooth, hard and corrosion resistant aluminium alloy conforming to IS 736 - Material Designation 24345 or 1900.

4.5.2 Aluminium Composite Materials (ACM)

ACM sheets used for sign boards is a sandwiched construction with a thermoplastic core of 'Low Density Polyethylene' (LDPE) between two thick skins/sheets of aluminium with overall thickness of 4 mm and 3 mm, and aluminium skin thickness of 0.4 - 0.5 mm and 0.25 - 0.3 mm respectively on both sides. The retro-reflective sheeting must be applied on the top surface with aluminium surface with recommended surface preparation from sheeting manufacture. A fluorocarbon coating may be applied over the exposed surface of aluminium to ensure corrosion resistant and weather proof and thus shall conform to relevant ASTM. The mechanical properties of 4 mm and 3mm ACM and that of its aluminium skin shall conform to the requirement given in Table 7.11, when tested in accordance with the test methods mentioned against each of them.

4.6 Plate Thickness

Shoulder mounted ground signs with a maximum side dimension not exceeding 600mm shall not be less than 1.5 mm thick with aluminium and 3 mm thick with aluminium composite material. All other signs shall be at least 2 mm thick with aluminium and 4 mm thick with aluminium composite material. The thickness of the sheet shall be related to the size of the sign and its support and shall be such that it does not bend or deform under prevailing wind and other loads. All overhead signs made with aluminium composite material shall be minimum 4 mm thick to withstand wind and other loads without deformation.

S. No.	Description	Specification for 4 mm		Specification for 3 mm
		Standard Test	Acceptable Value	Acceptable Value
A	**Mechanical Properties of ACM**			
1	Peel off strength with retro-reflective sheeting. (Drum Peel Test)	ASTM D903	Min. 4 N/mm	Min. 4 N/mm
2	Tensile strength	ASTM E638	Min. 40 N/mm^2	Min. 30 N/mm^2
3	0.2% Proof Stress	ASTM E638	Min. 34 N/mm^2	Min. 34 N/mm^2
4	Elongation	ASTM E638	Min. 6%	Min. 5%
5	Flexural strength	ASTM C393	Min. 130 N/mm^2	Min. 120 N/mm^2
6	Shear strength with punch shear test	ASTM D732	Min. 18 N/mm^2	Min. 18 N/mm^2
B	**Properties of Aluminium Skin**			
1	Tensile strength (Rm)	ASTM E8	Min. 150 N/mm^2	Min. 130 N/mm^2
2	Modulus of elasticity	ASTM E8	Min. 70,000 N/mm^2	Min. 70,000 N/mm^2
3	Elongation	ASTM E8	A_{50} Min. 2%	A_{50} Min. 2%
4	0.2 % Proof Stress	ASTM E8	Min. 110 N/mm^2	Min. 110 N/mm^2

Table 7.11 Specifications for Aluminium Composite Material (ACM)

4.7 Retro Reflective Sheeting

The retro reflective sheeting used on the signs shall consist of white or coloured sheeting having a smooth outer surface which has the property of retro reflective over its entire surface. It shall be weather resistant and exhibit colour fastness. It shall be new and unused and show no evidence of cracking, scaling, and painting, blistering, edge lifting or curling and shall have negligible shrinkage or expansion. A certificate of having the sheeting tested for coefficient of retro reflective, daytime colour and luminance, shrinkage, flexibility, liner removal, adhesion, impact resistance, specular gloss and fungus resistance, 3 years outdoor weathering and its having passed these tests shall be obtained from International/Government Laboratory/Institute by the manufacturer of the sheeting and in case the certificate is obtained from international agency, it should also be obtained from Indian agency within 3 years of launching of product by the manufacture in abroad. Alternatively, a certificate conforming to ASTM Specification (D 4956-09) on artificial accelerated weathering requirements from a reputed laboratory in India can be accepted provisionally. In such a situation, the Employer/Client, if so desires, could seek for a performance guarantee which would be released after receipt of certificate meeting the requirement of three years outdoor weathering of the sheeting. Retro reflective sheeting is divided into three classes as follows:

CLASS A SHEETING :- Engineering and Super Engineering Grade Sheeting as per ASTM D4956-09 Type I and II.

CLASS B SHEETING :- High Intensity and High Intensity Prismatic grade sheeting as per ASTM D4956-09 Type III and IV.

CLASS C SHEETING :- All Micro Prismatic grade sheets as per ASTM D4956-09 Type VIII, IX and XI.

4.7.1 Selection of Sheeting

Table 7.12 suggests a general guideline for selection of sheeting considering the performance characteristics of each type of sheeting for different category of roads and also on economic consideration and visibility requirements in Indian context. However, the choice for selection of type of sheeting would rest with the client.

Table 7.12Suggested Guidelines for Usage of Retro-Reflective Sheeting

Class of Sheeting	Type of Sheeting (ASTM)	Category of Road				
		National/State Highway	Major District roads	Rural Roads	Urban /City Roads	Expressway
Class A	Type I	No	Yes	Yes	No	No
	Type II	No	Yes	Yes	No	No
Class B	Type III*	Yes	Yes	Yes	Yes	No
	Type IV*	Yes	Yes	Yes	Yes	No
Class C	Type VIII	Yes	No	No	Yes	Yes
	Type IX	Yes	No	No	Yes	Yes
	Type XI	Yes	No	No	Yes	Yes

* Type III sheeting is available both as glass beaded and micro prismatic technology as per ASTM D4956-09. The light reflecting efficiency of glass beaded sheeting is lower than the micro prismatic sheeting.

Performance Characteristics of sheeting Type I to Type XI used for road signs ar and definition of key words are given in IRC: 67-2012. However, performance Characteristics of Class C sheeting prescribed for Urban/City Roads are presented hereunder.

4.7.2 Class C (Micro Prismatic grade sheeting)

4.7.2.1 Type VIII, IX &XI Micro prismatic grade sheeting

Retro-reflective sheeting is typically manufactured as a cube corner. The reflective sheeting shall be retro-reflective sheeting made of micro prismatic retro-reflective material. The retro-reflective surface, after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflective (determined in accordance with ASTM D: 4956-09) as indicated in **Table 7.13** for Type-VIII sheeting, **Table 7.14** for Type IX sheeting and **Table 7.15** for Type XI sheeting.

When totally wet, the sheeting shall show not less than 90 percent of the values of retro-reflection indicated in Table 7.13 to 7.15. At the end of 10 years, the sheeting shall retain at least 80 percent of its original retro-reflectance.

Table7.13 Acceptable Minimum Co-efficient of Retro-reflective for Type VIII Prismatic Grade Sheeting [A] (Candelas per Lux per Square Meter)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow-	Fluorescent Yellow	Fluorescent Orange
$0.1^{0\,B}$	-4^0	1000	750	375	100	150	45	30	800	600	300
$0.1^{0\,B}$	$+30^0$	460	345	175	46	69	21	14	370	280	135
0.2^{0}	-4^0	700	525	265	70	105	32	21	560	42	210
0.2^{0}	$+30^0$	325	245	120	33	49	15	10	260	200	95
0.5^{0}	-4^0	250	190	94	25	38	11	7.5	200	150	75
0.5^{0}	$+30^0$	115	86	43	12	17	5	3.5	92	69	35

A Minimum Co-efficient of Retro-reflective (R_A) ($cd.Ix^{-1}.m^{-2}$).

B Values for 0.1^{0} observation angles are supplementary requirements that small apply only when specified by the purchaser in the contract or order.

Table 7.14 Acceptable Minimum Co-efficient of Retro-reflective for Type IX Prismatic Grade Sheeting [A] (Candelas per Lux per Square Meter)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow-Green	Fluorescent Yellow	Fluorescent Orange
$0.1^{0\,B}$	-4^0	660	500	250	66	130	30	530	400	200
$0.1^{0\,B}$	$+30^0$	370	280	140	37	74	17	300	220	110
0.2^{0}	-4^0	380	285	145	38	76	17	300	230	115
0.2^{0}	$+30^0$	215	162	82	22	43	10	170	130	65
0.5^{0}	-4^0	240	180	90	24	48	11	190	145	72
0.5^{0}	$+30^0$	135	100	50	14	27	6	110	81	41
1.0^{0}	-4^0	80	60	30	8	16	3.6	64	48	24
1.0^{0}	$+30^0$	45	34	17	4.5	9.0	2	36	27	14

A Minimum Co-efficient of Retro-reflective (R_A) ($cd.Ix^{-1}.m^{-2}$).

B Values for 0.1^{0} observation angles are supplementary requirements that small apply only when specified by the purchaser in the contract or order.

Table 7.15 Acceptable Minimum Co-efficient of Retro-reflective for Type XI Prismatic Grade Sheeting [A] (Candelas per Lux per Square Meter)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow	Fluorescent Yellow	Fluorescent Orange
$0.1^{0\,B}$	-4^0	830	620	290	83	125	37	25	660	500	250
$0.1^{0\,B}$	$+30^0$	325	245	115	33	50	15	10	260	200	100
0.2^0	-4^0	580	435	200	58	87	26	17	460	350	175
0.2^0	$+30^0$	220	165	77	22	33	10	7	180	130	66
0.5^0	-4^0	420	315	150	42	63	19	13	340	250	125
0.5^0	$+30^0$	150	110	53	15	23	7	5	120	90	45
1.0^0	-4^0	120	90	42	12	18	5	4	90	72	36
1.0^0	$+30^0$	45	34	16	5	7	2	1	36	27	14

A Minimum Co-efficient of Retro-reflective (R_A) ($cd.Ix^{-1}.m^{-2}$).

B Values for 0.1^0 observation angles are supplementary requirements that small apply only when specified by the purchaser in the contract or order.

4.7.3 Adhesives

The sheeting shall have a pressure-sensitive adhesive of the aggressive-tack type requiring no heat, solvent or other preparation for adhesive to a smooth clean surface, in a manner recommended by the sheeting manufacture. The adhesive shall be protected by an easily removable liner (removable by peeling without soaking in water or other solvent) and shall be suitable for the type of material of the base plate used for the sign. The adhesive shall form a durable bond to smooth, corrosion and weather resistant surface of the base plate such that it shall not be possible to remove the sheeting from the sign base in one piece by use of sharp instrument. The sheeting shall be applied in accordance with the manufacture's specifications.

4.7.4 Fabrication

Surface to be reflectorised shall be effectively prepared to receive the retro-reflective sheeting. The aluminium sheeting shall be de-greased either by acid or hot alkaline etching and all scale/dust removed to obtain a smooth plain surface before the application of retro-reflective sheeting. If the surface is rough, approved surface primer may be used. After cleaning, metal shall not be handled, except by suitable device or clean canvas gloves, between all cleaning and preparation operation and application of reflective sheeting/primer. There shall be no opportunity for metal to come in contract with grease, oil or other contaminants prior to the application of retro-reflective sheeting. Complete sheets of the material shall be used on the signs except where it is unavoidable. At splices, sheeting with pressure-sensitive adhesives shall be overlapped not less than 5mm. Where screen printing with transparent colours is proposed, only but joint shall be used. The material shall cover the sign surface evenly and shall be free from twists, cracks and folds. Cut-outs to produce legends and borders shall be bonded with the sheeting in the manner specified by the manufacturer.

4.8 Messages/Borders

The messages (legends, letters, numerals, etc.) and borders shall either be screen-printed or of cut out from durable transparent overlay or cut-out from the same type of reflective sheeting for the cautionary and mandatory sign boards. Screen printing shall be processed and finished with materials and in a manner specified by the sheeting manufacturer. For the informatory and other sign boards, the messages (legends, letters, numerals, etc.)and borders shall be cut-out from durable transparent overlay film or cut-out from the same reflective sheeting only. Cut-outs shall be from durable transparent overlay materials as specified by the sheeting manufacturer and shall be bonded with the sheeting in the manner specified by the manufacturer. Whenever transparent overlay film is used for making any type of sign, the coloured portion of sign shall have coefficient or reflectivity not less than the reflectivity of type and colour of sheeting normally used. Cut-out messages and borders, wherever used, shall be either made out of retro-reflective sheeting or made out of durable transparent overlay except those in black which shall be of non-reflective sheeting or opaque in case of durable transparent overlay. Creating coloured areas by means of screen-printing with ink shall not be permitted.

4.9 Warranty and Durability

The retro reflective sheeting type " A" , "B" and "C" shall be covered respectively under 5,7, and 10 year warranty respectively issued for field performance including the screen printed areas and cut-out sheeting and cut-out durable transparent overlay film. The contract shall indicate the minimum retro-reflective of the signs at the end of the warranty period.

5.0 POSTS AND MOUNTINGS FOR SIGNS

5.1 The traffic signs shall be mounted on support posts, which may be of GI pipes conforming to IS 1239, Rectangular Hollow Section conforming to IS 4923 or Square Hollow Section conforming to IS 3589. In case of signs supported on two or more posts, if necessary, bracing may also be provided. Sign posts, their foundations and sign mountings shall be so constructed as to hold these in a proper and permanent position against the normal storm wind loads or displacement by vandalism. Normally, signs with an area up to 0.9 square meter shall be mounted on a single post, and for greater area, two or more supports shall be provided. Sign supports may be of mild steel, reinforced concrete (M25) or galvanized iron (GI Post) sections. End(s) shall be firmly fixed to the ground by means of properly designed foundation. The work of foundation shall conform to relevant Specifications as specified.

5.2 All components of signs and supports, other than the reflective portion of GI posts shall be thoroughly descaled, cleaned, primed and painted with two coats of eproxy paint. Any part of Mild Steel (MS) post below ground shall be painted with three coats of red lead paint.

5.3 The signs shall be fixed to the posts by welding in the case of steel posts and by bolts and washers of suitable size in the case of reinforced concrete or GI posts. After the nuts have been tightened, the tails of the bolts shall be furred over with a hammer to prevent removal.

5.4 For overhead signs, the support system should be properly designed based on sound engineering principles, to safely sustain the dead load, live load and wind load on the completed sign system. For this purpose, the overhead signs shall be designed to withstand a wind loading of 150 kg/m^2 normal to the face of the sign and 30

kg/m^2transverse to the face of the sign. In addition to the dead load of the structure, walkway loading of 250 kg concentrated live load shall also be considered for the design of the overhead sign structure.

6.0 Signs for Persons with Disabilities

6.1 The International Symbol of Accessibility

The International Symbol of Accessibility(ISA) is also known as the international wheelchair symbol. It is used as informatory sign with blue background and image of a person using a wheelchair overlaid in white. The wheel chair figure should always be seen facing right. The Sign/Symbol is given in IRC 67-2012.

6.2 Size, Shape and Colour

These signs shall be rectangular and have a blue background, while white symbol shall be displayed to indicate the facility. The size of the normal sign shall be 600 mm x 600 mm and the symbol shall be as shown in IRC:67-2012.

6.3 Parking Information

The parking area should be indicated using a signage to reserved vehicle parking for users with disabilities. Since, the wheelchair is always to be shown facing right, the direction of the parking should be indicated using an arrow. The Sign/Symbol is given in IRC 67-2012.

6.4 Ramped Entrance to Subway/ Over Bridge

These signs shall inform the persons with disabilities about the ramp facility to enter pedestrian subway/ foot over bridge. These signs shall be rectangular and have a blue background, while white symbol shall be displayed to indicate the facility. The Sign/Symbol is given in IRC 67-2012.

6.5 Telephone Facility

Telephone facility should be indicated using a signage for persons with disabilities. The Sign/Symbol is given in IRC 67-2012.

6.6 Toilet Facility

Toilet area should be indicated using a signage for persons with disabilities. The Sign/Symbol is given in IRC 67-2012.

6.7 Way Finding Sign for Disable

Way finding sign should be indicated using a signage for a disable person. The Sign/Symbol is given in IRC 67-2012.

7.0 Maintenance of Signs

7.1 Prior to installing any road sign, the responsibility for the maintenance of the sign and the post is required to be decided, and the timing plan(s) should be clearly established. Over time, signs become faded and their retro-reflective properties diminish. This reduces both conspicuity and legibility, by day and by night. Excessively discoloured or faded signs (e.g. white backgrounds which have become grey or brown, or red borders faded to pink) and signs, where the legend or graphic is peeling off cannot be fully effective and need to be replaced. The signs along with the posts shall be maintained in proper position, and kept clean and legible at all times.

Signs should be cleaned at intervals appropriate to the site conditions. Signs at locations where they are subject to heavy soiling from passing traffic, or algae growth (a common problem with signs beneath tree canopies) will need more frequent cleaning.

7.2 A reference number along with the month and year of installation should be placed on the back of a sign in a contrasting colour or by stamping in characters not exceeding 50 mm in height. It is distracting and unsightly to place reference numbers on the sign face or on the front of a backing board.

7.3 All signs shall be inspected at least twice a year both in day and night times and atleast once a year in the rain. All signs should be replaced at the end of the warranty period provided for the retro-reflective sheeting used on the sign. Damaged signs shall be replaced immediately.

7.4 The authorities responsible for road signs should maintain a schedule of painting of the posts and signs periodically. It is recommended that painting of the signs (where applicable) may be undertaken after every two years. In case of overhead signs, adequate provision is to be made to have access to the signs for the purpose of maintenance activities. Special care shall be taken to see that weeds, shrubbery, mud, etc. are not allowed to obscure any sign.

REFERENCES

1. Code of Practice for Road Signs- IRC:67-2012 (Third Revision)
2. New Traffic Signs- IRC:SP:31-1992 (Under Revision).
3. Specifications for Road and Bridge Works- Ministry of Surface Transport (Roads Wing)- Fifth Revision published in 2013.

APPENDIX·I

LIST OF MANDATORY/REGULATORY SIGNS

1. Stop and Give Way Signs

(i) Stop
(ii) Give Way
(iii) Give Way to Buses Exiting the Bus Bay

2. Prohibitory Signs

(i) Bullock Carts Prohibited
(ii) Bullock and Hand Carts Prohibited
(iii) Hand Cart Prohibited
(iv) Tongas Prohibited
(v) Horse Riding Prohibited
(vi) Caravan no Allowed
(vii) Buses Prohibited
(viii) Cars Prohibited
(ix) Trucks Prohibited
(x) Tractor Prohibited
(xi) Construction Vehicle Prohibited
(xii) Articulated Vehicles Movement Prohibited
(xiii) Two Wheeler Prohibited
(xiv) Cycles Prohibited
(xv) Horn Prohibited
(xvi) No entry
(xvii) One Way
(xviii) Left Turn Prohibited
(xix) RightTurn Prohibited
(xx) Overtaking Prohibited
(xxi) U-Turn Prohibited
(xxii) Right Turn &U-Turn Prohibited
(xxiii) Priority to vehicles from the Opposite Direction

3. No Parking and No Stopping Signs

(i) No Standing
(ii) No Stopping and No Standing
(iii) No Parking
(iv) Parking not Allowed on footpath
(v) Parking not Allowed on Half of Footpath

4. Speed Limit and Vehicle Control Signs

(i) Axle Load Limit
(ii) Height Limit
(iii) Length Limit
(iv) Load Limit
(v) Width Limit
(vi) Maximum Speed Limit
(vii) Maximum Speed Limit (Vehicle Type)
(viii) Stop for Police Check

5. Restriction Ends Signs

(i) Restriction Ends

6. Compulsory Direction Control and Other Signs

(i) Compulsory Ahead
(ii) Compulsory Ahead or Right Turn
(iii) Compulsory Ahead or Left Turn
(iv) Compulsory Turn Right
(v) Compulsory Turn Left
(vi) Compulsory Turn Right (In Advance of Junction)
(vii) Compulsory Turn Left (In Advance of Junction)
(viii) Compulsory Keep Left
(ix) Compulsory Keep Right
(x) Pass Either Side
(xi) Minimum Speed Limit
(xii) Compulsory Cycle Track/Cycle Only
(xiii) Compulsory Cyclist and Pedestrian Route
(xiv) Pedestrian Only
(xv) Compulsory Snow Chain
(xvi) Bus Way/Buses Only
(xvii) Compulsory Sound Horn

LIST OF CAUTlONARYIWARNING SIGNS

1. Left Hand Curve
2. Right Hand Curve
3. Right Hairpin Bend
4. Left Hairpin Bend
5. Right Reverse Bend
6. Left Reverse Bend
7. Series of Bend
8. Degree Loop
9. Side Road Right
10. Side Road Left
11. Y-Intersection
12. Cross Road
13. Roundabout
14. Traffic Signals
15. T-Intersection
16. T-Intersection Major Road Ahead
17. Major Road Ahead
18. Staggered Intersection
19. Merging Traffic Ahead (From Left)
20. Merging Traffic Ahead (From Right)
21. Narrow Road Ahead
22. Road Widens
23. Narrow Bridge Ahead
24. Steep Ascent
25. Steep Descent

26. Reduced Carriageway (Left Lane(s) Reduced)
27. Reduced Carriageway (Right Lane(s) Reduced)
28. Start of Dual Carriageway
29. End of Dual Carriageway
30. Gap in Median
31. Pedestrian Crossing
32. School Ahead
33. Built-up Area
34. Two Way Operation
35. Two Way Traffic on Cross Road Ahead Warning
36. Lane closed (Two Lane Carriageway)
37. Lane Closed (Three Lane Carriageway)
38. Lane Closed (Four Lane Carriageway)
39. Traffic Diversion on dual Carriageway)
40. Men at Work
41. Supplementary Plate “END” at the Leaving Side of Work Zone
42. Danger Warning
43. Deaf Persons Likely on Road Ahead
44. Blind Persons Likely on Road Ahead
45. Cycle Crossing
46. Cycle Route Ahead
47. Dangers Dip
48. Speed Breaker
49. Rumble Strip
50. Rough Road
51. Dangerous Ditch
52. Loose Gravel
53. Slippery Road
54. Slippery Road Because of Ice
55. Opening or Swing Bridge
56. Overhead Cables
57. Playground Ahead
58. Quay Side or River Bank
59. Barrier
60. Sudden Side Winds
61. Tunnel Ahead
62. Ferry
63. Trams Crossing
64. Falling Rocks
65. Cattle Crossing
66. Wild Animal
67. Queues Likely ahead
68. Airport
69. Unguarded Railway Crossing
70. Guarded Railway Crossing
71. Single Chevron (Normal)
72. Single Chevron (>100kmph Speed)
73. Double Chevron

74. Triple Chevron
75. Object Hazard (Left)
76. Object Hazard (Right)
77. Two way Hazard Marker

DIRECTION AND PLACE IDENTIFICATION SIGNS

1. Stack Type Advance Direction Sign (Shoulder Mounted)
2. Map Type Advance Direction Sign (Shoulder Mounted)
3. Map Type Advance Direction Sign for Roundabout (Shoulder Mounted)
4. Flag Type Direction Sign
5. Reassurance Sign
6. Place Identification Sign
7. Truck Lay
8. Toll Booth Ahead
9. Weigh Bridge Ahead
10. Gantry Mounted Advance Direction Sign Ahead of a Grade Separated Junction
11. Gantry Mounted Advance Direction Sign Ahead of an At-Grade Junction
12. Gantry Mounted Sign Far Advance of an Interchange in a Full Access Controlled Highway
13. Lane Dedicated Gantry Signs
14. Shoulder Mounted Sign in Advanced of a Grade Separated Junction in Full Access Controlled Highway
15. Expressway Sign
16. Gantry Mounted advanced direction sign ahead of a flyover in Urban/City Roads
17. Definition/Supplementary Plates

NOTE : Figures Given in IRC:67-2012

FACILITY INFORMATION SIGNS

1. Eating Place
2. Light Refreshment
3. Resting Place
4. First Aid Post
5. Toilet
6. Filling Station (Fuel Pump)
7. Hospital
8. Public Telephone
9. U- Turn Ahead
10. Pedestrian Subway
11. Foot Over Bridge
12. Chair Lift
13. Police Station
14. Picnic Site
15. Repair Facility
16. Railway Station/Metro Station/Monorail Station
17. Industrial Area
18. Cycle Rickshaw Stand
19. Taxi Stand

20. Auto Rickshaw Stand
21. Home Zone
22. Camp Site
23. Airport
24. Golf Course
25. National Heritage
26. No Through Road
27. No Through Side Road
28. Toll Road Ahead
29. Guide Sign on Toll Lane Portal
30. Country Border
31. Entry Ramp for Expressway
32. Exit Ramp for Expressway
33. Expressway Symbol
34. End of Expressway
35. Bus Stop
36. Bus Lane
37. Contra Flow Bus Lane
38. Cycle Flow
39. Cycle Flow Cycle Lane
40. Holiday Chalets
41. Emergency Exit

PARKING SIGNS

1. Parking
2. Auto Rickshaw Parking
3. Cycle Parking
4. Cycle Rickshaw Parking
5. Scooter and Motorcycle Parking
6. Taxi Parking
7. Park and Ride
8. Parking Restriction Signs for Traffic Management
9. Flood Gauge

SIGNS FOR DISABLED PERSONS

1. International symbol of Accessibility
2. Parking Information
3. Parking Areas
4. Ramped Entrance to Subway/Over Bridge
5. Telephone Facilities
6. Toilet Facilities
7. Way Finding

ROUTE MARKER SIGNS

1. State Highway Route Marker Sign
2. National Highway Route Marker Sign
3. Asian Highway Route Marker Sign
4. Expressway Route Marker Sign

CHAPTER-8

ROAD LIGHTING

1.0 Introduction

1.1 Artificial light is a triumph of human ingenuity over the regime of nature. It enables man to encroach uPon the time set apart by nature for rest and extend the period of all human activity, worthwhile or worthless. Mobility provides a vital link in the chain of hUman activity and illuminated roads are an essential requisite for increased mobility.

1.2 While using a road facility, both the pedestrian and the vehicle operator stand in continuous need of information input from the surroundings. At night time the need becomes indiSPensable for removal of uncertainly and help in taking a confident decision regarding the next step or manoeuvre with safety. For the vehicle operator the information need is more critical as he is in speed. Light fulfis this need to the extent of its adequacy.

1.3 Lighted roads.

i) Increase safety of the roaduser (with or without vehicle) from the point of view of traffic interaction.

ii) It enables roadusing Vehicles to achieve the design potential of the road in respect of speed, capacity etc. to the maximum possible extent during night and

iii) It also contributes to general public safety from the point of view of law and order and PreVention of crime. 1.4 It is a common knowledge that road safety reduces at night. At many locations this becomes evident from a comparison of the percentage of accidents after sun-set with that of the day time even when the total traffic volume during night time is considerably less specially on urban roads.
Statistics reveal that road lighting reduces the number of accidents considerably. (according to some authorities by about 25% to 35%).

2.0 Problem of Road use at night

2.1 Some of the reasons may lie in the technological deficiencies in the road vehicle itself. At night, even on a straight road the sight-distance allowed by the head-lights may be inadequate for moving at design speed. Also, while negotiating a curve the orientation of the headlight beam may not reveal the road along the curve and enable the driver to use the road in the same speed for which the road geometries have been designed. The contrast conditions among different road fixtures are also low during night, affecting driving speed of vehicle.

2.2 It will be evident from above that because of inherent deficiencies in the road vehicle, the presence or absence of day-light essentially require and enforce two different sets of geometric standards on the same road. Even thehighway design engineer is not always conscious of it.

2.3 It is however, very difficult and hardly ever possible for any driver to switch over to full extent to the new set of reflexes and reactions every twelve hours overcoming the fixed inertia of habits of daytime driving.

The result is that inspite of the compulsions imposed by absence or

inadequacy of light, the night time traffic speed does not significantly reduce. It is reported that in many countries the average reduction in speed during nigh is from 5km/hour to 7km/hour only. Increase in accidents may be the only logical consequence.

2.4 The visibility of an object at night from a moving vehicle is influenced by the following:-

(i) Size of the object,
(ii) degree of illumination and
(iii) its light or colour contrast with the carriage way surface.

2.4.1 For a driver observing from a vehicle in motion the visibility of the object decreases with decrease in its size. It is reported that an object 1.5 metre high is visible from a distance of 100 to 110 metres but an object of 0.5 metre size is visible only from a distance of 50 to 60 metres.

2.4.2 Because of the high cost involved in roadlighting, illumination is generally proposed at a level just sufficient to enable the driver to recognise the outline of an obstacle on the illuminated background of the carriageway surface. The intensity of illumination required for this is however, considerably less than the intensity required for a detailed examination and perception about the nature of the object, while the observer is still in motion. Any anticipation about the shift or change in its location is, therefore, very vague and the caution that the driver decides to exercise in the case to avoid collision with it is left completely to his individual discretion and decision at the moment.

2.4.3 Contrast in shade or colour holds the key to observation. The recognition of an object springs from the discrimination about the contrast in the luminance of the object and its background. It is said that visual perception mainly occurs by three methods i.e. the observation of Silhouette, reverse -silhouette or surface detail Silhouette is the formation of a dark area against a bright background, reverse-siihouette is that of a bright area against a dark back-ground and observation by surface detail occurs with a high order of direct illumination on the face of the object towards the driver.

Most obstacles on the carriageway are observed by silhouetting Generally the objects in areas adjacent to roadways and projections above the pavement surface like channelizing island, abutments and also upper portions of pedestrians and vehicles are observed by reverse silhouette. Discernment by surface details is the general method of 'seeing' in heavy traffic where background perception is very blurred and observation is principally by variation in brightness and colour over the own surface of the object. Most roadsigns are also observed by surface detail.

2.4.4 The basic principles behind road lighting design are therefore to facilitate silhouetting, reverse silhouetting and surface detail observations (alongwith reduction in glare or visual noise).

2.4.5 The most common form of observation for the vehicle driver is by silhouetting. One of the principal function of the fixed roadlight is, therefore, to increase the brightness and uniformity of illumination of the road surface background to improve silhouetting.

In creating the effect of brightness, the surface illumination and the reflection properties of the surface are equally important. The reflecting properties of the road surface depends on the surface texture, the extent of

polishing received by traffic, the material used in the surfacing and the colour of the road surface. A dark object on a block-topped carriageway needs greater general illumination than that on a newly constructed light coloured cement-concrete pavement. Age of the road surface is also an important factor since with time and age the light shade of the cement concrete pavement may become darker and also a matt surface may gain in polish through ageing with traffic and thereby change its reflective properties.

3.0 Common Photometric and Installation Terms connected with Road Lighting

The road engineer needs to be acquainted with certain common photometric and installation terms which may occur frequently during dealing with any road lighting case.

3.1 Common Photometric Terms

3.1.1 Luminous Flux (Light Flux)

This is the total amount of light emitted by a light source or received by a surface irrespective of the direction of emission as evaluated photometrically.

3.1.2 Lumen

The unit of luminous flux is the lumen. This is the flux emitted through a unit solid angle (a steradian) from a uniform point source of 1 candela. Since the whole space surrounding a point source subtends a solid angle of 4, a light source of one candela emits a total of 4 lumens.

3.1.3 Lower Hemispherical Flux or Downward Flux The luminous flux emitted by a luminaire in all directions below the horizontal.

3.1.4 Luminous Intensity

This is the strength or light-giving power (candle power) of a light-giving source in any direction. The unit of luminous intensity is the candela cd). Number of' candelas emitted by a light source will be its canle power (cp).

3.1.5 Illumination

This is the amount of luminous flux falling normally on a unit area.

3.1.6 Lux is the unit of illumination expressed in lumen per square metre. One lumen of light uniformly distributed over an area of one square metre will be considered to have the illumination of one lux.

3.1.7 Luminance

It is the technical term for brightness of a reflecting surface. It is the rate at which light is reflected from an illuminated surface from a unit projected area (area of surface viewed from that direction) in a given direction.

3.1.8 Luminosity

The attribute of visual sensation according to which an area appears to emit more or less light. It is sometimes called 'brightness'.

3.1.9 Light output

The Luminous flux emitted by a luminaire.

3.1.10 Light Distribution

The distribution of luminous intensity from a luminaire in various directions in space.

There are, in general, two types of distribution 'Symmetrical' (or

Asymmetrical) and Axial (or Non-axial).

.3.1.11 Mean Hemispherical Intensity
The downward flux divided by 2. This is the average intensity in the lower hemisphere.

3.1.12 Intensity Ratio
The ratio of an actual intensity from the luminariein a particular direction to the mean hemispherical intensity.

3.1.13 Peak Intensity Ratio
The ratio of the maximum intensity to the mean hemispherical intensity of the light emitted below the horizontal.

3.1.14 Coefficient of utilization
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.

3.2 Lighting Installation Terms

3.2.1 Lighting Installation
It comprises of the total equipment used for provision of lighting a highway i.e. lamps, luminaries, supports, electrical implements and associated materials.

3.2.2 Lighting System
The characteristic light distribution intended in the installation. The common systems are 'cut off, 'semi-cut off and 'non-cut-off.'
(i) Cut-off System
In this system the candle power per 1000 lumens does not exceed 10 cd at an angle of 90^0 above nadir (i.e. at the horizontal) and 30 cd at a vertical angle of 80^0 above nadir.
The direction of maximum intensity may vary but should be below 65^0.
(ii.) Semi-Cut-Off System
In this system the candle power per 1000 lumens does not exceed 50 cd at an angle of 90^0 above nadir (i.e. at the horizontal) and 100 cd at a vertical angle of 80^0 above nadir.
The direction of maximum intensity may vary but should be below 75^0.
(iii) Non-Cut-Off System
The system in which there is no candle-power limitation in the zone above the maximum candle-power is termed 'non-cut-off system.

3.2.3 Lantern
The light source or the bulb emitting light is termed 'lamp'.

3.2.4 Luminarie
The lamp together with its accessories like housing, reflector, refractor, diffuser etc. i.e. the complete lighting assembly (excluding the support system etc.) is called the luminaire.

3.2.5 Outreach
This is the horizontal distance measured between the centre of a luminarie mounted on a bracket and the centre of the supporting column or wall-face.

3.2.6 Overhang
The horizontal distance between the centre of the luminaire and the adjacent edge of the carriageway.

3.2.7 Mounting Height
This is the vertical distance between the surface of the carriageway and the centre of the luminarie.

3.2.8 Spacing
The distance between successive luminaries in any arrangement measured parallel to the centre-line of the carriageway.

3.2.9 Span The length of the highway which lies between successive luminaries is called the span.

3.2.10 Arrangement
The pattern according to which luminaries are sited on plan, like staggered, axial, opposite etc.

4.0 Sources of Light

4.1 Selection of light source is an important work and several considerations are required to be made in deciding about the source.
4.1.1 In order to be affordable the ligh.t source must be efficient and economic. These qualities hinge on the duration of life and the output of luminous flux. An economic light source shall have a reasonably long life and its luminous efficacy i.e. the number of lumens produced per watt of energy spent shall be high.

4.1.2 The dimensions of the light source are important factors.
4.1.3 The colour quality of light or the rendition of colour of an object by lightis another important consideration.

4.1.4 It shall also be borne in mind that the light output of the source undergoes changes during its life period and this effect is to be taken into consideration.

4.2 The most commonly used light sources are the different types of gaseous discharge lamps or vapour lamps.

4.2.1 Mercury Lamps
This type of lamp has been used on various outdoor applications from a long time. Its lamplifeis long but as the luminous efficiency is less compared to other new sources in use in the present time, it is being gradually edged out in its application.

4.2.2 High Pressure Mercury Vapour Lamp (HPMV LAMP)
Generally this type of lamp is appropriate for locations where high power is required but rendition of colour is not that important. HPMV lamps with fluorescent bulbs are used where appearance of correct colour is also important.

HPMV lamps generally have long life and high luminous efficiency

4.2.3 Mercury-Halide Lamps
This is an improved version of HPMV lamp which allows good colour rendition along with high luminous efficiency.

4.2.4 Tubular Fluorescent Lamps
These have good colour rendering power as well as high luminous efficiency although capacity for high powers may not be there. These may be used in situations where larger number of luminarie installation may not be aesthetically unsuitable.

4.2.5 Low Pressure Sodium Vapour Lamp Its luminous efficiency is high but does not have a good colour quality. It is widely used where economy in the use of energy outweigh the need of colour rendition. Use of these lamps are considered good where foggy condition is common.

4.2.6 High Pressure sodium Vapour Lamp
This version tries to get over the deficiency of the low pressure sodium vapour lamp by improving the colour rendition quality. It has better colour, good luminous efficiency and a reasonably long life. However, the lamp cost is comparatively high.
4.2.7 LED Lamp : Latest introduction is LED Lamps having low energy consumption and long burning life. This is likely to be the further lighting.

5.0 <u>Glare Problem</u>
To avoid wastage of light energy an ideal light source requires arrangement to reduce or prevent distribution of light in directions in which it . is not of any use to the road using traffic (upward to the horizontal) as well as to produce increased luminosity at certain range of higher angles down- ward of the horizontal so that the light intensity on the pavement at a distance is increased to produce a uniform light patch inspite of its diminishing with distance due to inverse square law.

5.2 However, incident light on the driver's eye above the horizontal and too intense a light on the whole visual field may creature problems of glare for the driver.

5.3 Two variations of glare have generally been recognized. The first one is termed discomfort glare as it causes a sensation of annoyance and discomfort to the driver and prevents adequate perception. The second one is termed 'disability glare' as it produces a too intense and uniform light on the object area obliterating contrast· discernment and may produce full or partial loss of perception about the presence of objects.

5.4 The disconcerting effects of glare are sought to be got over by several ingenuous ways in modern luminaire design practices, such as
(i). By increasing the luminaire height,
(ii) By increasing the effective luminaire area,
(iii) By restricting the light at vertical and horizontal angles where it interferes with driver visibility and
(iv) By increasing the background brightness and contrast.

6.0 Broad Guidelines for Road Lighting Design

In a non-urban situation the decision regarding provision of lighting will primarily depend on the status or classification of the road i.e. whether it is a Freeway, Expressway or Major Arterial route or a road of lower category. Information regarding night traffic volume, percent of exit and entry traffic, speed, accident rate, accident type, pedestrian volume etc. have also to be collected for consideration. Dependinq upon the availability of funds, possibility of supply of power etc. decision about continuous lighting or alternatively partial lighting in accident-prone areas, interchanges, tunnels and under passes etc. can be taken.

6.2 Continuous lighting may be desirable in most urban situations specially where both sides of the road are built up. If for economic or other reasons, complete continuous lighting is not possible, minimum safety lighting provisions can be considered covering intersections, interchanges, under-passes, major points of conflict or geometric complexity. Merging areas may be lighted so that the main road traffic can clearly observe the point of entry for side traffic. The main road for a length before the merge point may be lighted so that the entering traffic can have an idea of the speed and distance of main road traffic. Intersections alongwith kerb faces, road-signs and other vertical/horizontal obstructions can be made clearly visible to the traffic by (partial) lighting of these areas only. Pedestrian cross-walks may be properly lighted. The lighting effort at any particular location should always of more than one luminaire or with a group of luminaries suitably p1aced and not by a single luminarie anywhere.

6.3 Inter - changes, park areas or areas with complex geometrical features etc. may preferably be provided with a high-mast light for provision of a general, uniformly lighted background in addition to lower-intensity luminarie groups provided by design.

6.4 The eye requires rapid adaptation in passing from a lighted zone to a dark one. As this is dependent on time and the driver is negotiating the area in speed the situation becomes still more critical for the driver. The end of a lighted zone to a dark one, should not therefore be abrupt but with the provision of suitable transition light of lower or half-intensity for a short length to prepare the driver for the change in visual condition eitherway.

6.5 Even for a continuously lighted urban section there may be different levels of lighting depending upon area classification like industries commercial, residential area etc.

6.6 The best effect is achieved by continuous and uniform lighting. Tt must be true even for situations where special lighting is provided such (near cross-roads, sharp bends, bridges, tunnels etcand it may be ensure that the principle of uniformity and gradual tapering are observed.

6.7 Direction signs, guard posts, and other features of traffic islands ma be made prominent at night by special lighting without giving rise to glare.

7.0 **light Distribution**

7.1 Luminaries are sometimes categorised as 'short distribution' 'medium distribution' and 'long distribution'.

The categorisation is based on the distance from the luminaire where the light beam of maximum candle power strikes the road way surface. This distance is usually indicated in terms of the mounting height. The design criterion is to keep the luminaries spacing such that the maximum candle power beams of adjacent luminaries merge into one another to produce a continuous lighted area of uniform intensity instead of patches of alternate bright and dark areas. The mounting height may be larger as the power of the lamp increases. IS-1944 (Part 1&11) suggests that 'as a general rule heights of 9 to 10 meters are suitable for its Group A roads (explained in subsequent paragraphs) and 7.5 to 9 metres for Group B roads. Heights of less than 7.5 metres are undesirable except in certain special cases, such as the lighting of residential roads or roads bordered by trees'.

7.2 Code also suggests that to preserve the longitudinal uniformity the spacingshould generally not be greater than the values given below:

8.0 **Arrangement of Installation**

Arrangement of installation and provision of light support is generally decided on consideration of roadway width, the width of median available, presence or absence of median barriers and the total cost of project. There are four general type of arrangement as described below.

8.1 Single side arrangement

For narrow roads, generally in residential areas single side arrangement is provided. As expected the illumination on the road surface on the side further from the luminarie will be slightly lower. If both sides are not built up the lamp support may be provided on the built-up side. The arrangement is recommended where the carriage way width is equal to or less than the mounting height in which case the lighting will be quite adequate and economical.

8.2 Staggered two-side arrangement

For roads of medium width, location of luminaries on either side of carriageway in a zig-zag formation may provide more uniform illumination and better visib.tity on both sides. This arrangement is recommended for carriageway widths not exceeding 15 times the mounting height.

8.3 Two side arrangement (opposite)

Two side arrangement with mountings opposite to each othet is recommended for carriageway widths exceeding 1-5 times the mounting height.

8.4 Axial arrangement

If the road has divided carriageway with adequate median width axial or central support arrangement may be resorted to.

This arrangement cuts down the cost of luminarie support and conductor material conduit cost drastically and also gives an overall aesthetic look to the roadway. It is therefore quite common.

This arrangement, however, has its limitations for roads with wide carriageway. In the axial or median support arrangement the stress on illumination reduces towards the shoulder and thus drawing more traffic at night towards the median end creating imbalance in carriageway utilization. Also, the illumination is inadequate on the edge farther from the median where there is more likelihood of objects and obstruction appearing and also entry of traffic increasing the potential for accidents:

9.0 Special Considerations for siting of Luminaires

9.1 From what has been discussed earlier it is clear that the ratio of the spacing to the mounting height and also the ratio of the width of the carriageway to the mounting height is very important for. balanced lighting and requires careful attention in any design.

In addition the colour of the road surface and its surface texture (both macroscopic and micro-scopic) determine many important factors like the size, dimensions and the brightness of the lighted patch.

9.2 From the point of view of aesthetics the support columns for the lights should merge with the general architectural characteristics of the surrounding area and they should not interfere or obstruct the best views of an important architectural or historical building. They are usually placed in between two buildings, if possible. Near important monuments, bridges and on processional roads they should have a matching

and formal design. For all such design the services of specialised architects may have to be requisitioned.

9.3 In minor bridges (structures not exceeding 60 m in length) the normal road lighting system adopted in the approaches may be continued across, care being taken to ensure that the entrance to and the exit from the structure and the edge of the footpath are clearly visible. It may also be ensured that each side entrance to the bridge has a light point irrespective of the arrangement followed. In case of bridges/underpasses having restricted clearance, adequate warning signs/posts must be displayed sufficiently in advance of bridge ..In case such structures are old, their entry point configuration can be lighted with retroreflective tape or studs to give driver an idea of cross sectional details of the structure.

9.4 In long bridges confusion generally arises because of absence of background for better visibility. Cut-off type luminaries may be used to reduce glare. Where objects cannot be silhouetted properly illuminate them directly. In general, lighting requirement for bridges should be given detailed consideration at a very early stage so that the structural requirements can be suitably incorporated during the design of the bridge structure itself.

9.5 Curves of very large radius, say .1000m or more may be treated as straight. In curves of smaller radius, luminaries are preferably placed only on the outside of the bend for effective beaconing of the curve.

9.6 For better visibility of pedestrian crossing, road markinqs, the crossinJ$_1$ mark should occur midway between two consecutive luminaries situated 0", either side of the carriageway. Luminaries should never be sited just prior to the road crossing marking.

9.7 Based on the principles of good lighting, the IS Code (1944-Part I & 11) recommend siting of luminaires for different possible situations at intersections. These are indicated in Appendix-llI·tothis chapter and may be followed.

10.0 Classification of Lighting

The Indian Standard code of Practice for Lighting of public Thoroughfares (IS -1944-part 1& 111970) divides road lighting into the following categories.

Group A :For main roads. This is sub-divided into two categories.

Group A :1 - For very important routes with rapid and dense traffic where the only considerations are the safety and speed. Facilities, the aspects of both breakdown maintenance as well as preventive maintenance should be given serious attention.

The following items of work shall form the minimum core of tenance activities:-

(i) Preparation and observation of a strict periodic schedule of inspection of installations by supervisory as well as higher officers.

(ii) Immediate replacement of defective or non-functioning lamps.

The IS-1944 recommends that lamps should not be left extinguished for more than one night.

(iii) Timely replacement of lamps which have fallen below a certain tolerable level of efficiency,

(iv) Periodic cleaning of lamps, luminaries and support systems.
(v) Periodic inspection of mains, supply lines, earthings and stability of the support structures.
(vi) An annual inspection of areas to assess if there is any need to upgrade or modify lighting installation systems because of / gradual change in character of localities, increase in vehicle population and road use or detection of accident prone areas.

REFERENCES

Code of Practice for Lighting of Public thoroughfares- Part, I,ll, V & VII of IS: 1944, Delhi Electric Supply Undertaking Circulars
Road and their Traffic - Earnest Davies.
Transportation and Traffic Engineering Handbook - Institution of Transportation Engineering - USA

APPENDIX

(Extracts from-IS-1944 Par 1& 11 Code Of Practice for Lighting of Public Thoroughfares)

CLASSIACATlON OF UGHTlNG INSTALLATION AND LEVELS OF ILLUMINATION

Classification of Lighting Installation	Type of Road	Average Level of Illumination on Road Surface (Lux)	Ratio Minimum Average Illumination	Transverse Variation 0' Illuminator (percent)
(1)	(2)	(3)	(4)	(5)
GroupA1	Important traffic routes carrying fast traffic	ro	0,4	33
GroupA2	Other main roads carrying mixed traffic, like main city streets, arterial roads, throughways, etc	15	0.4	33
GroupB1	Secondary roads with medium to heavy traffic	8	0.3	20
GroupB2	Secondary roads with light traffic	4	0,3	

APPENDIX - II

General Guidelines for Road Lighting Installations in Delhi by Delhi Vidyut Board (DVB)

1. Since incandescent lamps are not energy efficient no new scheme shall be prepared by DVB incorporating use of incandescent bulb points.
2. The bulb points in 15 ft. wide backlanes, which had earlier been provided with incandescent bulb points shall now be equipped with tube lights.
3. Roads with 30ft to 45 ft. width Steel tubular poles of 6.6 metre height shall be provided on one side only with 70 watts High Pressure Sodium Vapour (HPSV) lamp and fittings at 25 metres spacing.
4. Roads with 60 ft. 80 ft. and 100 ft. width Steel tubular poles of 9.1 metre height shall be provided with 150 watts HPSV lamps with fittings shall be provided at 30 metres spacing on both sides of the road in staggered formation.
5. Roads with more than 100 ft. width. Steel tubular poles with height of 10.5 metres or 11.86 metres shall be installed in the central verge of the road. The spacing may be 30 metres as at present or less depending on the width of the carriageway. The supports will be equipped with 250 watts HPSV lamps and fittings.

PART. III :
DRAINAGE AND MAINTENANCE

CHAPTER-9

ROAD DRAINAGE

1.0 Introduction

Adequate drainage is a primary requirements for maintaining the structural soundness and functional efficiency of a road. Pavement structure including subgrade must be protected from any ingress of water; otherwise over a period of time it may weaken the subgrade by saturating it and cause distress in the pavement structure. That is why rapid dispersal of water from pavement and subgrade is a basic consideration in road design. Also, proper drainage takes away the water from pavement surface quickly and reduces the chance of skidding of vehicles. Because of inadequate surface and subgrade drainage, the structural stability of pavement is undermined by.

a) Weakening of pavement structure and subgrade through infiltration of water from the top, and

(b)Erosion of shoulders, verges and embankment slopes caused by water running off the pavement.

1.1 In road works, interception, collection, removal and disposal of surface water, ground water or water trapped in the pavement structure usually go by the general name of 'drainage'. All devices, appurtenances and constructions/provisions made to facilitate the above shall be considered as constituentsof the ‘drainage system'. The urban drainage can be detailed into :-

(i) Road Surface Drainage

(ii) Sub-Soil drainage/Sub-surface drainage

(iii) Infiltration into the ground for recharging of ground water table.

(iv) Disposal of rain water.

1.2 The intercepting drain in a cut section located away from the road pavement, the side ditch at the toe of the road embankment, the road pavement with its crown and camber, the dressed shoulders, the side-slope chutes, the sub-surface drains, the kerb inlets, underground storm water drains, culverts, bridges, all form the elements of the total drainage system to protect and ensure unhindered performance of the constructed road.

1.3 A road drainage system must satisfy two main criteria if it is to be effective throughout its design life:

a) It must drain surface and subsurface water away from the roadway and dispose it in a way that prevents excessive collection of water in unstable areas and subsequent downstream erosion

1.4 Drainage problems and requirement of remedial provisions for the same may be broadly subdivided under two categories i.e. surface and sub-surface drainage depending on the location and level of activity of the water to be drained.

2.0 Surface Drainage

2.1 Damages due to surface water

2.1.1 In general, drainage efforts consist of separating surface water from its continuous contact with the road and remove it to a safe disposal as quickly as possible to save the road from damage.

2.1.2 While flowing down the shoulders and side-slopes the water causes erosion and again deposits the material causing siltation at other points, both requiring provision of measures to reduce the damage due to each .

2.1.3 If the road surface profile is not correct and conducive to quick drainage,pools of water may form resulting in weakening and undermining the pavement course strength and leading to skidding, hydroplaning or plain splashing of water which is a nuisance to other vehicles and road-users.

2.1.4 Free flowing water acts as the carrier of fine silt, clay and other particles and deposits them in the fine cracks in the bituminous pavements preventing their subsequent healing and seasonal thermal cracks which then tend to become permanent lines of separation in the long run.

2.1.5 One major cause of pothole formation on road surface is due to inadequate storm water disposal mechanism.

2.2 Provisions for surface drainage

2.2.1 For quickly draining out surface water it is necessary to make adequate provision of intercepting drains, open side drains or ditches and covered or underground drains where surface area available is not sufficient for accommodating them.

2.2.2 Intercepting drains

Interception, as the name indicates will always be preferable (before the water reaches the area vulnerable to damage) at a higher level if in a steep cut slope or sufficiently away from the shoulder and carriageway of the road in ordinary cases. In addition to providing adequate depth for the intercepting drain, a small edge-bund can also be constructed on one side to prevent over-topping of water.

2.2.3 Ditches/Side-Drains/Gutters

2.2.4 Disposal: Water collected in intercepting drains and roadside ditches shall be released at planned locations

(i) at the end of cut-slope,

(ii) at valley curves,

(iii) when the length of the ditch is long then at intermediate locations with low points in the road profile,

(iv) at natural water courses.

If a road has the same type of grade continuously for a long length, the carriageway itself may act like a conduit during rains and may need judicious provision of 'V' drains, or saucer drains at the end of shoulder or pavement or diagonal drains along shoulders filled up with stones and pebbles (Since provision of cuts in shoulders may prove dangerous for traffic). The roadside ditch-drain to carry surface drainage may also be designed to drain off the base of the road pavement course to prevent saturation and loss of support.

2.2.5 Chutes

In high embankments and approaches to bridges/ over bridge, if the water is allowed to leave the carriageway at undefined spots, it may cause serious damages to

the embankment and eventually undermines the pavement. In each location, rain water is collected in small manageable quantities through longitudinal kerb channel and brought down through stepped chutes without damage to slope. The chutes may be lined with cement concrete on stable supports and may be located at 10 metres to 15 metres interval depending upon the rainfall and width of carriageway.

Finally all the water will come down to the toe of the road embankment and if the collection has erosive potential, then construction of steps or simple energy dissipation structures may need to be taken up. A perspective view of arrangement of such 'chute' and energy dissipation on structure is given in the fig. 9.6.

2.2.6 Channel shapes

The usual channel shapes are

(i) Parabolic,

(ii) Trapezoidal or rectangular,

(iii) Triangular or 'V' shaped.

The parabolic profile is considered to be the best for hydraulic flow but its actual construction and maintenance is difficult. The 'V' shaped drain is not very popular in urban areas as its desilting is difficult. I urban areas all drains passing through built up area and near to bus stand, crossing etc should preferably be covered so that the drains are not used as dust-bins. However, it should be kept in mind that pipe drains are difficult to desilt and maintain.

The trapezoidal section is easy to construct and may be suitable at most locations.

(ii) For unlined channels of the above shapes the side-slopes should be a minimum of 2:1 (H:V) and preferably 4:1. A flatter slope is considered safer from traffic point of view. The bottom width will depend upon capacity requirement and may vary from 0.3 metre to 1.25 metre.

(iii) For fixing design capacity of open, unlined side-channels usually no hydraulic calculations are made although Manning's formula can be used. The size is fixed by experience on the basis of knowledge of rainfall in the area and site inspection.

(iv) When the side-ditch is also to be used for draining the pavement courses, the bottom of the ditch shall be placed at least 0.45 metre to 0.6 metre (preferably the latter) below the sub grade level, care being taken in capacity fixing so that the surface flow quantity does not exceed 0.3 metre depth. The pavement course percolation is normally negligible and need not be added but the total depth of an open ditch should not exceed 1 metre when unlined and 1.5 metre when lined.

An alternative method of drainage from pavement is to extend a properly designed sub-base layer upto the shoulder end and expose it to the side- slope with an inverted filter at the end so that it can freely drain into the ditch along the slope face.

2.2.7 Problems of Velocity

(i) The flowing mass of water creates problem both at very high velocity and at very low velocity; The main influencing factor of velocity is the grade or slope of the bed. The higher limit or restriction on velocity will be placed by grade coupled with the type of material and roughness of the lining which will determine the amount of friction to flow.

Similarly, the lower limit to velocity will be dictated by the material load of the flowing water which will start depositing silt in case the velocity is lower than desirable.

(ii) A convenient solution is to follow the road grade, if it is possible. But if the grade of the road is very flat or level, in order to have the minimum self cleansing velocity the drain has to go deeper and to shift away from the road side to accommodate the side slopes required. In case on new road construction in flat terrain, it will be preferable to provide sloping grade to road to obviate deep cutting for the drain and take out water from suitably located valley point.

On the other hand if the road grade is steep, the drain will become deep and away from the road in the area near the top of the slope and flat and near to the road at lower levels of the road grade.

(iii) To avoid problems due to loss of normal velocity in a different season or during

an occasional drought etc. the design section may be provided with a small 'V' channel at the centre of the lining to increase the flow to self-cleansing velocity.

Similarly, in a high velocity case the channel bed may have to be provided with checks to reduce velocity and the bed and the sides provided with lining to reduce erosion.

2.2.8 Lining

If the grade of the channel bed is not very flat (less than 0.5%) or very steep (more than 5%) grass lining will do. At a very sluggish flow the grass may be destroyed by silting and at a very fast flow by erosion.

In high velocity cases, if fund permits, paved lining may be provided with cement concrete by machine-laid continuous construction or by pre-fabricated cement concrete slabs, brick or stone-masonry in standard desings, by boulder pitching, spreading impervious polythene sheets or with 25mm to 40mm thick bituminous concrete mix.

2.2.9 Broad Guidelines for Road sides Ditches or Open Drains

To sum up it may be useful to remember the following thumb-rules for ditches and drains.

(i) The area of flow should be adequate to accommodate storm flow and slightly more and depth should be sufficient to be able to drain the pavement flow. In general, area should be such that depth of water in the channel due to surface flow should not exceed 0.3 metre. The invert of the drain should preferably 0.6 metre below subgrade level in order to drain the pavement.

(ii) Keep velocity low enough to prevent erosion and sufficiently high to prevent deposition and silting. Normally a self cleaning velocity will be achieved at a minimum 0.5% grade of the bed.

(iii) Provide necessary lining with grass or other material as required by the velocity of the flow.

(iv) On a level ground or in cutting, the side drain may preferably be 3 metres away from the edge of the carriageway.

In low embankment it should be at least 1 metre to 3 metres way from the embankment toe. When the drain is not provided with a lining, try to locate it beyond the meeting point of a 4H:IV imaginary line drawn from the edge of the shoulder as indicated in IRC-10-1961.

In high embankment cases the allowable proximity shall be fixed after full stability analysis of the embankment taking the channel into account.

(v) For discharge, provide outlets to natural water courses at the earliest opportunity for discharge.

4.0 Sub-surface Drainage

4.1 Depending on the permeability of the receiving layer some percentage of the precipitation incident on the ground surface invariably seeps downwards. Rains falling directly on the surface, flow of water on and along the surface and collection of water in potholes, undulations etc. all contribute to seepage. When the traditional granular construction is provided on a relatively low permeability sub grade, the granular sub-base should be extended to entire formation width. With the same intention it is suggested that as far as practicable and in case in any major through roads, the base should be constructed 30-45cm wider than the required bituminous surfacing so that the run-off water disperses harmlessly and clear off the main carriageway. Drainage of pavements on impermeable sub grade is shown in fig. 9.6.

Ingress of moisture takes place from three directions i.e. percolation from the top, seepage from the sides (through shoulders and verges) and by capillary action from ground water below.

4.2 Damages due to sub-surface water Sub-surface water may harm the road in various ways.

(i) The presence of water reduces subgrade strength. The strength of granular bases/subbases are stress-dependent and poor strength in subgrade affects the performance of the top granular layers also.

(ii) Presence of excess moisture can weaken granular bases, cement treated bases and stabilised layers by changing the arrangement of fine to coarse material and aggregates in the structure.

(iii) Absorption of water in the filler material, which is on many occasions not fully non-plastic, may seriously undermine the load support characteristics of the layer.

(iv) Free water in bituminous pavements speeds up the process of oxidation and loss of resilience in the binder leading to faster cracking and deterioration.

(v) When there is excess moisture in the pavement layers, heavy wheel-loads may create pulsating water-pressure resulting in internal erosion and ejection of materials through cracks and joints.

(vi) Because of changed permeability in the layers of materials of different courses, water accumulates at interface of layers and this layer of water affects the flexible pavement performance by reducing load-spreading and load-transfer capacity of the pavement courses.

4.3 Sub-surface Drains

As per IRC-37, the difference between formation level and level of water table/high flow should normally be not less than 0.6-1.0 metre. Since, however, in most urban areas the percentage of built-up surface area is very high, situations with problems of sub-surface trouble may not be frequent unless the water table is unusually high and the sub grade soil is poor from the point of view of drainage.

Briefly speaking, sub-surface drainage can be effected by installation of solid pipes with open joints, or porous concrete pipes/perforated pipes and sometimes by provision of free-draining material. As has already been stated earlier, base-course drainage may be effectively achieved by providing and extending a specially designed sub base layer upto the embankment slope face. Sub surface drainage can also be effected by using suitably designed geotextiles. Geotextiles fabric may be woven or non-woven of polypropylene, polyethylene or polyester formed into stable network such that filament or yarn retain their relative position to each other. Method of lyingof geotextiles shall be as per para 702 of section 700 of MOST specification (third revision 1995). By combining filter and drainage function in one material, drainage geocomposite can be effectively used as sub-surface drains.

4.4 Broad Guidelines for sub-surface drains

It may be useful to remember the following thumb-rules for sub-surface drains.

(i) Try to locate the drain on the water face side at the bottom of a pervious layer with the invert level 10 to 15 cm below it.

For intercepting side flow, it may be placed at the end of the shoulder and for lowering ground water level it may be placed at the end of the carriageway.

(ii) It should be at least 1 metre to 1.25 metre deep and should have a minimum slope of 0.15% for efficient functioning.

(iii) The outlet of the subsurface drain shall be slightly over hangings or projecting beyond embankment slope and the location should not be such as to be affected by silting or scouring. The point should be easily accessible for inspection and maintenance.

5.0 Design considerations for drains

5.1.0 Road profile for better drainage.

Rain water on the carriageway will get collected in the drain. For quick discharge into the drain without stagnation and taking minimum time in flowing along the carriageway, it is necessary that the carriageway is provided with adequate camber. The provision of camber on carriageway is guided by the recommendations of IRC-86:1983 (Geometric Design standards for urban Roads in plains) some relevant portions of which are mentioned in the following paragraphs for recapitulation.

The higher value of the camber shall be provided in areas with high intensity of rainfall and where ponding is feared due to some reason. Also steeper camber should be provided on kerbed pavements to minimise spread of surface water flows.

5.1.1 For shoulders along unkerbed pavement, the cross fall shall be at least 0.5 percent steeper than that of the pavement subject to the minimum values indicated below:-

WBM surface	3 Percent
Gravel surface	4 Percent
Earth surface	5 Percent

In addition, it is necessary that shoulders are not higher than adjoining pavement surface to prevent pooling of water at the edge of carriageway and for quick drainage.

5.1.2 For paved footpaths a cross-fall of 3 to 4 percent should be adopted. For verges and unpaved areas the cross-fall should be 4 to 6 percent.

Undivided carriageways should have a crownin the middle and slope towards the edges. Divided carriageways may have a single-crowned section in the middle with straight cross fall on each divided carriageway or in very special cases separate crowned sections for each carriageway if the conditions of abutting property and drainage provisions available so require.

5.1.3 The water from the road surface should flow towards outer edge of carriageway into kerb channel. The kerb channel should be 30 cm wide with smooth finish and should have a minimum transverse slope of 1 in 6.

The longitudinal slope of the kerb channel will be dictated by the road gradient. The kerb channel will discharge its flow into pipes called bell- mouths which are generally 250mm diameter non-pressure RCC pipes. These pipes are placed under the footpath at about 30 metre interval.The spacing may require to be adjusted depending on the longitudinal slope ofthe road. The bell-mouth will discharge water into the road side drain.

5.1.4 For roads with superelevation at curves the bell-mouth pipe shall be provided on the inner side only. For divided carriageway with superelevation, paired channel may be provided in the central verge with inlets at 10 metre interval depending upon the longitudinal gradient.

5.2.0 Storm Water Drainage Design.

Broadly speaking there shall be two components of the design. The first component will be calculation of the total discharge that the system willrequire to drain off and the second will be fixing the dimensions of the drainto have adequate capacity to carry the discharge.

5.2.1 The ideal method of calculation of discharge will be the rational method of hydrologic design dealt in detail in chapter 6 of IRC Special Publication No.42 of 2014and chapter-6 of IRC:SP:50-2013.

Stated in brief, the rational method uses an empirical formula relating run-off to rainfall and is applicable to small catchment areas not exceeding 50 km^2. The formula as per IRC:SP:42-2014 is as below:-

$Q = 0.028PfAl$

And as per IRC:SP:50-2013, the formula is as below:

$Q = 0.028PAI_C$

Where, Q = Discharge (Peak run-off) in cumecs.

P = Co-efficient of run-off for the given catchment characteristics.

f = Spread factor for converting point rainfall into a real mean rainfall. IRC:SP:42-2014 suggests a relationship between the spread factor and catchment area. F factor can be worked out from the curve given in Fig. 6.1 of IRC:SP:42-2014.

A = Area of catchment in hectares and

I_C = Critical intensity of rainfall in cm per hour for the selected frequency and the duration equal to time of concentration.

There is a table indicating the suggested values of the co-efficient of run-off 'P'. These are indicated in Appendix I to this chapter.

5.2.2 Because of the cumbersome nature of analysis involved and the difficulty of determining correctly the concentration time etc. presently discharge calculations for storm water drain for urban areas is not being done on a rational basis. Based on past experience and performance, the current practice being followed in Delhi is as follows:

(i) The average value of runoff which is adopted for different category of drains is as follows:

a) Internal drains ($0.177m^3$/ha) - 1 cusec/acre

b) Intercepting drains ($0.132m^3$/ha) - 0.75 cusec/acre

c) Main drain ($0.088m^3$/ha) - 0.5 cusec/acre

The above values have been worked out on following assumptions. Rainfall intensity of 30 minutes duration at the rate 2.5" (62.5 mm) per hour occurs once in two years. Time of concentration 30 minutes and the average runoff coefficient adopted is 0.60. The gives average runoff for internal drains as 0.088 cum/ha. Considering that

flooding at streets for an hour or so may be allowed and the drains are designed for a runoff of 1 cusec/acre.

For intercepting drains, time of concentration considered in 30 minutes and runoff coefficient adopted is 0.7. The average runoff is taken as 0.13 cum/ha as against calculated value of 0.177 cum/ha. In case of main drains, time of concentration considered is one hour and the corresponding intensity of rainfall as 42 mm (1.65”) per hour occurring once in 2 years. The average runoff coefficient adopted is 0.30 which gives runoff 0.5 cusec/acre.

For unimportant routine work, the design may be based on the above figures. In case of road side storm water drain is likely to receive effluent from the road side abutting properties, in that case drain section should be decided in consultation with the local municipal engineer and drain section should be got duly approved by him.

However, considering the rising expectations of Public for no flooding after rains, design may be done considering both public expectations and economical considerations.

5.2.3 For the hydraulic design of the channel, the relationship expressed by Manning's formula for uniform flow in open channels can be used as below:

$Q = 1/n \times AR^{2/3} S^{1/2}$ and $V = 1/n \times R^{2/3} S^{1/2}$ Where

Q=discharge in cum/Sec,

V=Mean velocity in m/sec,

n =Manning's roughness co-efficient,

R = hydraulic radius in m i.e. area of flow cross-section divided by wetted perimeter,

S=energy slope of the channel, which is roughly taken as slope of the drain bed and .

A =Area of the flow cross section in m^2.

Values of roughness coefficient 'n' and maximum permissible velocity of flow in open channels have been suggested in detail for various type of surfaces in IRC-SP-42 and the same are reproduced below for convenience of readers. :

Table 9.2 Manning's 'n' Values and Maximum Permissible Velocities for Drain.

S.No.	Ditch Lining	Manning's 'n'	Allowable Velocity to Prevent Erosion m/sec.
(1)	**(2)**	**(3)**	**(4)**
1.	**Natural Earth**		
A.	**Without Vegetation**		
	i) Rock		
	Smooth & Uniform	0.035-0.040	6
	Jagged & irregular	0.04-0.045	4.5-5.5
	ii) Soils (Extended Casagrande Classification)		
	G.W.		
	G.P.	0.022-0.024	1.8-2-1
	G.C.	0.023-0.026	2.1-2.4
	G.F.	0.020-0.026	1.5-2.1
	S.W.	0.024-0.026	1.5-2.1
	S.P.	0.020-0.024	0.3-0.6
	S.C.	0.022-0.024	0.3-0.6
	S.F.	0.020-0.023	0.6-0.9
	CL and CT	0.023-0.025	0.9-1.2
	MI and ML	0.022-0.024	0.6-0.9
	OL and OI	0.023-0.024	0.9-1.2
	CH	0.022-0.024	0.6-0.9
	MH	0.022-0.023	0.6-0.9
	OH	0.023-0.024	0.9-1.5
	Pt	0.022-0.024	0.6-0.9

		0.022-0.025	0.6-0.9
B.	**With Vegetation**		
	Average turf		
	Erosion resistant soil	0.050-0.070	1.2-1.5
	Easily eroded soil		
	Dense turf	0.030-0.050	0.9-1.2
	Erosion resistant soil		
	Easily eroded soil	0.070-0.090	1.0-2.4
	Clean bottom with bushes on sides		
	Channel with tress stumps	0.040-0.50	1.5-1.8
	Channel with tree stumps	0.050-0.080	1.2-1.5
	With sprouts		
	Dense weeds		
	Dense brush		
	Dense willows	0.040-0.050	1.5-2.1
		0.060-0.080	1.8-2.4
		0.080-0.012	1.5-1.8
		0.100-0.140	1.2-1.5
		0.150-0.200	2.4-2.7
2.	**Paved**		
A.	**Concrete with all Surfaces, Good or Poor**		
	i) Trowel finished		
	ii) Float finished	0.012-0.014	6

	iii) Formed, no finish	0.013-0.015	6
		0.014-0.014	6
B.	**Concrete Bottom, Float Finished, with Sides of**		
	i) Dressed stone in mortar		
	ii) Random stone in mortar	0.015-0.017	5.4-6
	iii) Dressed stone or smooth concrete rubble (Rip-rap)	0.017-0.20	5.1-5.7
	iv) Rubble or random stone (Rip-rap)	0.020-0.025	4.5
		0.025-0.030	4.5
C.	**Gravel bottom with sides of**		
	i) Formed concrete	0.017-0.020	3
	ii) Random stone in mortar	0.020-0.038	2.4-3
	iii) Random stone or rubble (Rip-rap)	0.023-0.033	2.4-3
D.	**Brick**	**0.014-0.017**	**3**
E.	**Bitumen (Asphalt)**	**0.013-0.016**	**5.4-6**

5.2.4 While deciding the drain sections, it is not enough that they are sufficient to carry the required discharge, guidelines given in **Table 9.3**are also required to be kept in view.

Table 9.3 Minimum and Maximum velocities

S.No.	Type of Drain	Minimum m/sec.	Maximum m/sec
i)	Internal drain (brick pitched or plastered)	0.45	1.5
ii)	Intercepting and main drains (brick pitched or plastered)	0.75	1.5
iii)	Pipe drain (running full)	0.75	1.8

To ensure self cleaning of the drain, a minimum velocity of 1.5m per second may be desirable. However, this may require installation of concrete drains or paved drains.

5.2.5Minimum Freeboard

A minimum free board as indicated below shall be provided:-

Table 9.4. FREEBOARD FOR DIFFERENT DRAIN SIZES

S.No.	Drain Size	Free board
1.	Upto 300mm bed width	10 Cm.
2.	Beyond 300mm and upto 900mm bed width	15 Cm.
3.	Beyond 900mm and upto 1500mm width	30 CM.

For larger drains the free board shall be higher upto 90 cm depending upon the discharge.

5.2.6 The effective section of the drain carrying design discharge should be considered below the bell mouth pipe so that there is no back flow of water on to the road.

For drains with trapezoidal section the side slopes shall be at least 2V: 1H or flatter depending upon the type of soil. The drain will be designed for running in full condition excluding freeboard. For pipe culvert the design may be for running full.

For rectangular drain the economical section is obtained when the width of the drain (b) is twice the depth (d).

For trapezoidal drain with side slope of 2V:1H the economic section is obtained when bed width is equal to 1.24 times depth. In case of section with 1 V: 1H, the economical section is obtained when b=0.82d where 'b' indicates width and 'd' depth.

6.0 General Guidelines for storm water drains

After deciding about the cross-section, invert level and type of drain, the construction of the drain shall be commenced from the downstream side. From the point of view of better maintenance and ease in cleaning, anopen drain is preferable to pipe drains. If the drain is required to be covered, manholes at 10 metres interval or removable precast slabs at 5 metres interval shall be provided. The invert level of the manhole shall be at least 30cm lower than the invert lever of the pipe. This helps in trapping the silt in the manhole and reducing silting in the pipe. The minimum size of the manhole chamber shall be 1.2mx 0.9m, the 1.2 metre side being in the direction of the drain. The beds, side walls of drains and head walls etc. where provided shall have to be tested for their structural stability and soundness of design for each of the section provided. Drainage problem in underpass requires special attention. Water flows along open sloping portion of underpass. This should be interrupted at the end of grade and carried to an underground tank. The pumphouse should be located at the nearest possible location to underpass. The capacity of underground tank should be sufficient to store water of one week of highest rainfall. There must be a watch and ward during monsoon to check water in tank and to pump it out within week after heavy monsoon.

7.0 Maintenance of Drains

7.1 The drainage system is at its best, when it is maintained properly as designed. For this purpose, it is necessary that the drains keep their shape and slope in the designed manner during their life time. It is also necessary to ensure that the drains retain their full cross section, particularly for the monsoons. The system of maintenance can be classified into following three categories.

a) Continuous regular maintenance

b) Periodical maintenance

c) Special maintenance/Repairs for improvement

The extent of these repairs depends upon size of the drain, location of the drain, nature of habitation nearby and cross drainage structures. The difficulty in maintenance is also caused by a lesser degree of consciousness/civic sense. Malba, garbage, solid waste and road cleanings enter the drain resulting in silting and solidification of extraneous material making the maintenance difficult and reducing efficiency. A broad check list is given below.

Broad Checklist for Maintenance of Drains

1) Pavement crown or cross slope is maintained in design profile conducive to quick drainage.
2) Road shoulders are clear and dressed for efficient clear off.
3) If there is a need for new side drain chutes in high embankment.
4) If the kerb channel is clean and slopes towards the inlet is to be provided.
5) If the kerb inlets/bell mouths are clear.
6) The drain is desilted before rainy seasons, all manholes and grit chambers are leaned.
7) Inspection after heavy rains is required to know the deficiencies in the system and reporting unsatisfactory performance and also rectifications.
8) Inspection in October/November can be carried out and list defects for summer maintenance.
9) Gratings/metallic covers should be checked before monsoon for repair or replacement if any.
10) Discourage & enforce street, house sweeping being dumped into open drains or gutter openings.

7.2 Failure of drains may occur more due to deficiency in maintenance rather than defect in design. The principal activities in maintenance may be

- De-silting
- Cleaning of weeds
- Cleaning of obstruction, debris and blockage.
- Repairing of lining immediately at the commencement of damage or deterioration.

7.2.1 PWD has drains along approximately 1000 roads in Delhi. These drains have been originally constructed either by MCD or by DDA. The maintenance of these

drains was earlier with MCD & these drains were transferred to PWD for desilting in the year 2012. Most of these drains, i.e approximately 60% carry mix flow, i.e. sewerage flow during the year and also storm water during monsoon. These drains carrying mix flow are not designed for sewerage and it causes design failure resulting in water logging during rains, These drains require desilting/cleaning throughout the year to keep them in running condition.

7.3 Before the onset of monsoon all the drains shall be thoroughly de-silted. In case of pipe drains, if it is not possible to desilt manually, suitable mechanical device may be employed. As a part of monitoring exercise of desilting work, Executive Engineer shall have detailed information -for each road reaches like; length, shape, size of the drain, whether covered or uncovered, approximate quantity of silt (based on sample desilting on eachdrain) before execution of desilting operation. This information should beprogressively enriched by adding further monitoring parameters like method of desilting employed, actual quantity of silt extracted, amount paid etc. Such consolidated information can be gainfully used for desilting operation undertaken subsequently. Each de-silting case shall be 100% inspected by the Junior Engineer, at least 50% of them by the Asstt. Engineer and 25% of them by the Executive Engineer. It is recommended that local residents, public representatives are also taken into confidence and work executed is shown to them as a part of public relation exercise by field engineers.

7.4 Similarly, frequent inspection is a 'must' for intercepting drains as these drains fail more because of inaccessibility and consequent absence of inspection, choking and blocking, leading to seepage and failure. An intercepting drain located at a higher level may become the cause for slips' and slides at lower level, if the drain gets blocked due to some reason.

7.5 All 'kutcha' or unpaved side drains require dressing and deepening before the monsoon. Keeping the out-fall structures and cross' drains in a state of repair is also very important.

7.6 Normally, effluents and discharges from other types of sewers shall not be allowed in the storm water drains.

REFERENCES

Guidelines on Road Drainage- IRC:SP:42-2014.

Proceeding of the Seminar on Maintenance and Drainage Aspects of road Pavement-Bangalore, July 1-4 1982.

Draft manual for grade separatorIISE No.:2-1996.

APPENDIX· I

(Extracts from IRC-SP-42-2014- Guidelines on Road Drainage) Suggested Values of Coefficient of Run-off

S.No.	Description of Surface	Coefficient of Run-off (P)
1.	Steep bare rock and watertight pavement surface (concrete or bitumen)	0.90
2.	Steep rock with some vegetative cover	0.80
3.	Plateau area with light vegetative cover	0.70
4.	Bare stiff clayey soils (Impervious soils)	0.60
5.	Stiff clayey soils (impervious soils) with vegetative cover and uneven paved road surfaces	0.50
6.	Loam lightly cultivated or covered and macadam or gravel roads	0.40
7.	Loam Largey cultivated or turfed	0.30
8.	Sandy soil, light growth parks, gardens, lawn &meadows	0.20
9.	Sandy soil covered with heavy bush or wooded/forested areas	Q.10

Extracts from IRC:SP:50-2013- Guidelines on Urban Drainage

Suggested values of Co-efficient of Run-Off

S. No.	Description of Surface	Coefficient of Run-off (P)
1.	Watertight pavement surface (concrete or bitumen), steep bare rock.	0.90
2.	Green area (Loamy)	0.30
3.	Green area (Sandy)	0.20
4.	Unpaved area along roads	0.30
5.	Lawns and parks	0.15
6.	Flat built up area with about 60 percent area impervious	0.55
7.	Moderately steep built up area with about 70 percent area impervious	0.80

Table 6.2 Co-efficient of Run-off for various surfaces

S. No.	Description of Surface	Co-efficient of Run-off
1.	Most densely built up areas	0.7 to 0.9
2.	For adjoining area to built up areas	0.5 to 0.7
3.	Residential areas	0.25 to 0.5
4.	Sub-urban areas with few building	0.10 to 0.25

CHAPTER·10

ROAD MAINTENANCE

1.0 Introduction

1.1 Preserving a facility at its created level of quality and serviceability perhaps is more difficult than creating the facility at the first instance importance, however, can never be over-emphasised. Since things have a natural tendency to deteriorate with time and use, the effort itself is endeavour against natural flow and is therefore never destined to be fully successful. Nevertheless, preservation is life and a road is only as good it is maintained. All provisions, actions and treatments made with an eye repair, restore and rejuvenate the constructed highway to carry out its functions without strengthening and reconstruction may be a part of maintenance work.

1.2 Broadly speaking, the maintenance work mentioned above include the following different activities.

- Restoration of all wear and tear due to use of road by traffic like patching, pothole filling, crack sealing, surface renewal, joint repairs etc.
- All steps to keep the facility clear and unobstructed for use a: well as to save it from damage like clearing atmospheric precipitation (rain, snow etc.), removal of dust and litter and adoption of measures for dust control etc.
- All measures for promotion of safety of road use including removal of stranded vehicles or vehicles involved in accidents pruning the branches of road side trees, keeping in good shape the road signs, road markings, road lights etc.
- Preparing inventory of road, collecting basic data regarding all aspects of traffic, keeping records of accidents and analyses of the same and traffic survey, actual field measurement roughness, surface irregularity etc. will also be counted within maintenance effort.

2.0 Importance of Maintenance

2.1 Badly maintained roads invariably lead to below optimum utilisation of the system and the capacity and investment locked in the construction may, therefore, become partially in fructuous. Timely and proper maintenance will prolong the life of a pavement system.

2.2 Badly maintained roads increase the wear and tear of vehicles and adds to the vehicle operation cost.

It also increases travel time and when the travel time cost is taken into account the total cost of road use increases still further.

2.3 Badly maintained roads may also increase accident rates and maybecome indirectly responsible for substantial amount of accident cost.

2.4 The rate of deterioration in the surface condition of a badly maintained road may be very high and the extent and cost of damage repair will also be substantially higher than roads in normal cycle of maintenance. The life of the road will be shorter with more extensive and costly reconstruction required at frequent interval, so much so that the total overall extra expenditure on the roads, on the vehicle and to the road user may outweigh the expenditure which would have been required for normal cyclical maintenance.

Either way, therefore, people pay for the maintenance of road, whether or not the same is done and perhaps pay more dearly when maintenance is not done.

3.0 Classification of Maintenance Work

3.1 Traditionally maintenance works are categorised into the following subdivision:

(i) Ordinary Repairs,

(ii) PeriodicRenewals,

(iii) SpecialRepairsand

(iv) Emergent Repairs.

3.2 Ordinary Repairs

This is the day-to-day maintenance work for the road and will cover in its fold all restoration measures for minor deficiencies and normal wear and tear like patching,

pot-hole filling, crack sealing, shoulder dressing, maintenance. of drainage channels etc.

3.3 PeriodicRenewal

Depending on the life and durability of the type of surfacing provided, the road surface will require the provision of a renewal coat at the end of periodic cycles. For each category of surfacing a normal life periodicity is known and the maintenance unit is supposed to keep records of time and the type of renewal provided and also carry out inspection of surface condition from time to time to assess its needs.

For urban roads the re-painting of the road markings and re-furbishing of road signs shall also be counted within periodic renewal requirement.

3.4 Special Repairs

The repair activity under this category may include minor works of original nature to improve the facility like improvement to curves to increasevisibility, minor repairs to culverts, bridges etc.

3.5 Emergent Repairs

There may be some contingent situations in the life of a road when the surfacing and even the pavement courses may require renewal earlier to their design life or partial reconstruction due to accelerated damage as a result of intense rainfall or floods, cyclones/landslides etc. or simply due to traffic being more severe and intense than originally anticipated or due to some deficiency in the material or construction of the existing highway.

4.0 Maintenance Needs and Their Identification

4.1 The assessment of the overall condition of a pavement is the first step towards its maintenance. The main elements contributing to the performance can be measured by the observation of riding comfort supported by measurement of surface characteristic like roughness, skidding etc. and the structural adequacy can be determined by deflections test etc. to arrive at a rationally determined maintenance /rehabilitation proposal. Usually the condition survey will be carried out at least twice during a year i.e. once before the monsoon and again after it. The visual survey is carried out from a vehicle at slow speed and on foot for detailed inspection of badly affected stretches.

This may need the use of special equipment at times but will provide the satisfaction for having a rational basis for the adopted measures. Mostly, however, what the average road maintenance engineer will be required to do is to carry out a visual condition assessment and select and provide the essential intervention measures based on the same. This not only increases the responsibility of the assessor but also requires in the assessor a high degree of experience and knowledge about the general road ailments and ability to identify different types of distresses and their causes and he is also required to be conversant with the various types of remedial measures to be adopted. Only the road engineer's familiarity with the different symptoms of distress and their causes and an in-depth knowledge about his road can help him in the task. Generally the material and specifications used by the road engineer to attend to a given maintenance requirement of a road shall be of same type as used for existing bituminous surface. A mix superior to the one on existing surface can also be considered appropriate for repair work. In any case, the maintenance treatment should be compatible with the existing road surface. The different types of distress and their external signs are discussed in the following paragraphs.

4.2 Distresses and Failures

The distress in a pavement has external manifestation in various forms like cracks, heaving, corrugation, rutting, shoving, ravelling, potholes etc. The same form of distress may appear for many divergent reasons. The description below will, therefore, be based on the general and probable reasons only and the remedial measures mentioned are also only suggestive in nature.

4.3 Broadly speaking the underlying causes of distress/failure could be due to one of the following :-

(i) Because of fatigue due to the pavement being subjected to un- estimated overload without maintenance intervention at the right time.

(ii) Use of deficient material i.e. lack of quality control in material during construction,

(iii) Poor or deficient construction technique i.e. lack of process control in construction and

(iv) Structural inadequacy in base/sub-base courses or in subgrade material i.e. design deficiency.

4.4 Further, according to the nature of distress and the type and severity of the damage produced, the problems can be categorised as below:-

(i) Surface Deficiencies,

(ii) Cracking,

(iii)Deformation and

(iv) Disintegration

5.0 Surface Deficiencies

5.1 Bleeding/Flushing/Fatty Surface:

Description :

Upward migration of free bitumen on the pavement surface, leading to the appearance of a film of bitumen cement on the surface of the pavement. The pavement will have a sticky and shiny reflecting surface specially during hot noon.

Probable Causes :

(i) Use of excess bitumen in tack coat or material mix or putting tack coat when actual conditions did not need it.

(ii) Use of wrong grade of bitumen and use of bitumen not properly heated.

(iii) Loss of cover aggregate due to some reason or non-uniform spreading of cover aggregate or incorrect grading or quantity of aggregate for the bitumen used.

(iv) It may sometimes occur as a result of excessively heavy axle-load of traffic.

Condition:

Medium : Stickiness of surface and slight tyre mark.

High : Gives a wet look to the pavement surface, distinct tyre and trackmark and produces typical tyre noise.

Remedial Treatment :

(a) Sand blinding or blotting with hot sand in moderate cases.

(b) Surfacing with thin layer of open graded premix with a low bitumen content.

(c) Special methods such as burning of the excess binder.

(d) In case of large areas of fatty surface having irregularities, removal of the affected layer in the area and replacing it with a layer having a properly designed mix, may be necessary.

5.2 Slippery/Polished Surface/Smooth Surface

Description : May be a slight variant of the previous (5.1) case with presence of both free bitumen from flushing and use of coarse aggregates which become easily polished.

Remedial Treatment:

Laying a new course of rough-textured premix carpet or surface dressing Care should be taken to select hard and angular aggregates, which have proven non-polishing characteristics. A slurry seal can also be used to impart anti-skidding texture with the use of special aggregate.

5.3 Hungry Surface

Description: Discolouration of surface giving a typical look of pavement starved of bitumen accompanied with fine cracks and loss of aggregate.

Probable Causes : Use of less bitumen or highly absorptive aggregates.

Remedial Treatment: Slurry seal or fog seal.

6.0 Cracking

6.1 Depending on the temperature of the surrounding, all materials are bound to expand or contract with change in temperature. Again depending upon the material behaviour in that temperature (i.e. whether it flows or not visible or invisible cracks may appear on the surface. The first enquiry should, therefore, be *directed* towards finding whether under the temperature of the time, and for the type of use made the crack appearing *in* the material is normal orab normal. It has been seen that because of the shear deformation characteristics and tensile strength of the

material, the cracks generally develop into certain typical patterns depending upon the cause and origin of the stress. For detailed observation of cracks, on foot inspection is necessary. Cracks may appear generally parallel to the direction of traffic but with repeated loading transverse cracks will also take place giving it a blocky pattern. Also, generally, closely spaced cracking will indicate distress near the surface and widely spaced cracking is indicative of distress in a deeper layer. Crack widths may also give away the order in which the cracks have originated, with wider cracks having formed earlier to finer ones.

6.2 Longitudinal and Transverse Cracking

Description: Cracks appearing usually along the wheel path and may form an early sign of subsequent alligator cracking. Transverse cracks will generally extend across the pavement at approximately right angles to the pavement edge. Full transverse cracks tend to be regularly spaced along the length of the road, half transverse and the part transverse cracks occur at shorter intermediate distance . If both longitudinal and transverse cracks have already taken place the surface will be termed as 'Spalled'.

Probable Causes:

(i) Horizontal movement in the pavement course because of absence of stability in the asphalt surfacing course,

(ii) Heavy traffic load combined with weak pavement.

(iii) Brittleness and natural shrinkage due to very low emperature, frost action etc.

(iv) Poor drainage condition in pavement and shoulder.

(v) High temperature susceptibility of asphalt cement binder in 'the asphaltic mix.

(vi) Deep but isolated settlement in subgrade, sub-base or base-course and may generally occur near edges or loose fills near pipes/ducts,

(vii) Reflection cracking.

(viii) Poorly constructed longitudinal joints in the lower asphalt courses.

Condition:

Low: Hairline cracks with no spalling Medium : Cracks slightly spalled with narrow but defined crack lines. High: Single or multiple cracking with spalling and prominent crack width.

Remedial Treatment:

If the pavement is structurally sound, only crack-sealing with slurry seal or fog seal will do. If the structure is inadequate then full investigation and rehabilitation provisions as per results of investigation will be needed,

6.3 Edge Cracking

Description:

Edge cracks are parallel to the outer edge of the pavement and usually within 0.3m to 0.5m inside from the edge. Cracking is either fairly straight or consists of crescent-shaped cracks in wave formation. Progressive edge cracking may gradually encroach upon the outer wheel-track.

Probable Causes:

(i) Insufficient pavement strength or excessive loading at the pavement edge.

(ii) Poor drainage at the pavement edge and shoulder.

(iii) Lack of lateral support from shoulder.

(iv) Inadequate pavement width forcing heavy traffic too close to edge,

(v) Frost action in cold climates.

Condition :

Low : Single or two parallel cracks quite near to the pavement edge.

Medium: Multiple cracks with connecting links at a medium distance from the pavement edge.

High: Cracks extending over a considerable distance from pavement edge tending to become very close near edge.

Remedial Treatment:

If it is of low intensity no action except close monitoring is required. In other cases

spray patch, hot mix patch or spot patch and even single course full width hot mix resurfacing may be required according to the degree of severity.

6.4 Alligator Cracking

Description:

Alligator cracks are numerous, short, inter-connecting cracks forming a net-work of multi-sides (polygon) blocks making the surface look like the skin of an alligator. These cracks may occur anywhere on the pavement surface.

Probable Causes:

(i) Insufficient pavement strength,

(ii) Un-stable subgrade or base layers,

(iii) Poor base drainage,

(iv) Stiff or brittle asphalt mix applied at cold temperature.

Condition:

Low: Alligator pattern established with corners of polygon fracturing,

Medium: Alligator pattern established with spalling of polygon blocks.

High: Polygon blocks beginning to lift with or without forming potholes.

Remedial Treatment:

For 'Iow' condition not much action required but close monitoring is necessary. For other conditions spray patch/cold mix patch/hot mix patch with or without drainage improvement required as per severity. If the pavement is found to be structurally unsound full investigation and rehabilitation as per findings may be required.

6.5 Chicken-wire Cracking

These cracks probably occurs for the same reason as alligator cracking but with location of failure in a layer near the surface. Under such cracks pavement fractures into smallpieces.

Remedial Treatment:

Same treatment as in alligator cracking.

6.6 Block Cracking

Description:

Block cracks are large interconnected cracks that divide the pavement roughly into rectangular blocks. Block cracking differs from alligator cracking in that, alligator cracks form small many sided pieces with sharp angles unlike large rectangular blocks.

Probable causes:

Same as those of alligator cracking.

Remedial Treatment:

Same as those of alligator cracking.

6.7 Map Cracking

Description:

The transverse and longitudinal cracks appear to have combined to form a map. They may run randomly along the pavement surface, sometimes in an irregular serpentine manner.

Possible Causes:

(i)Swelling or shrinkage in the underlying layers.

(ii) Because of frost action in cold climates.

Remedial Treatment:

Provision of sand seal, or similar surface treatments like hotmix patch or single course hotmix resurfacing depending upon the condition or severity.

6.8 Hair Cracking

Description:

Short and fine cracks at close interval on the surface.

Probable Causes:

(i) Insufficient bitumen,

(ii) Excessive filler

(iii) Improper compaction including occasionallyover-rolling of the

asphalt during construction. When more than optimum roller effort is used or he asphalt viscosity or temperature is incorrect for rolling, a fissured or chickened surface may result).

Condition: Mostly low, may be local or general.

Remedial Treatment:

Sometimes disappears without treatment with use of road traffic. General treatment is crack sealing or fog sealing.

6.9 Slippage Cracking

Description :

Slippage cracks are crescent or half-moon shaped cracks with two ends pointing away from the direction. of traffic. Generally associated with slippage deformation.

Probable cause :

(i) Generally produced when unusually strong braking wheelor starting wheel hrusts cause the pavement surface to slide or deform.

(ii) Lack offailure of bond between surface and lower pavement courses. Remedial Treatment :

Removal of the surface layer in the affected area and replacement with well designed high stability fresh material. Use of mastic may also be tried.

6.10 Shrinkage Cracks

Description:

Cracks in transverse direction or inter-connected cracks forming a series of large blocks.

Probable Cause :

.Shrinkage of bituminous layers with age. Condition Classification :

Medium to low.

Remedial Treatment : May sometimes disappear with use of road traffic.

The cracks can be treated by Crack-sealing or fog sealing.

6.11 ReflectionCracks

Description :

Cracks appearing nearly at the same location (above) and more or less in the same shape in the surfacing course as in the lower layers.

Probable Causes:

Sympathetic cracks over joints or cracks in the pavement underneath. May generally appear when rigid pavements are resurfaced with bituminous materials. Cracks appear and reflect up through the overlay surface at the location of joints and cracks in the concrete. below.

Condition :

Will generally exhibit the same condition as below. May be evident at regular interval over construction and dummy joints in the rigid slab below. It may also occur in case of two layered asphalt pavements when the lower layer is badly cracked and have not been properly repaired .

Remedial Treatment :

Asphaltic surfacing layers containing geogrids may improve the road surface aesthetics. When cracks are of large magnitude consultation with experts in each case may be required.

Note: In. case of treatment of cracks in general, it should be remembered that when the pavement is structurally sound, cracks may be filled with a low viscosity binder or provided with slurry seal or fog seal depending on the width of the cracks. Cracked pavement which are evidently due to structurally unsound crust. thorough investigation and provisions of strengthening/rehabilitation measures are required after proper design.

7.0 Deformation

Deformation is change of shape in the pavement surface which may generally occur due to original poor compaction in the lower pavement layers. subsequently suffering densification due to traffic action. If the top bituminous surfacing consists of a mix of good quality. the depression may form without cracking the surface. A sharp shallow depression may be as a result of densification of a layer

near the surface and a large broad depression may indicate that the defect lies in a deeper layer.

7.1 Rutting

Description:

Rutting is characterised by longitudinal depression of large length along the wheel track. may be accompanied by upheavals alongside which in the long run may actually break-up the asphalt surfacing. Its presence becomes very clear after rain due to pending along depressions.

Probable Causes :

(i) Heavy channelised traffic along the same track line,

(ii) Poor compaction and poor stability of pavement material. Rutting is considered to be a definite evidence of shear deformation where the underlying layer is not sufficiently stable to support the load imposed on it.

(iii) May occur due to heavy bullock cart traffic also.

Condition:

Low: Less than 1 cm deepnoticeable only after rains.

Medium: Upto 2 cm deep, noticeable even without rain.

High: Greater than 2 cm in depth with clearly evident depression.

Remedial Treatment:

For low condition not much action is required except monitoring. For medium to high condition cold patching and hot mix patching along the area of depression can be undertaken. Situation indicative of shear failure or subgrade movement generally require excavation.

7.2 Slipping

Slipping is a deficiency, characterised both by cracking and deformation. Generally caused by relative movement between the surface layer and the lower layer. This distress usually occurs when there is a low-strength surface mix or poor bond between the surface and the next layer of the pavement structure. It is characterised by the formation of crescent shaped cracks. Since lack of bond or provision of adequate tack

coat is one of thereasons, the treatment will consist of removing the surface layer around up to the point where good bond between surfacing and the layer underneath exists and patching the same with premix material after providing proper tack coat.

7.3 Corrugation

Description: Development of undulations in the form of closely spacedridges and valleys occurring at a fairly regular interval. The ridges will generally be perpendicular to the direction of traffic.

Probable Causes: Lack of stability in the mix.

(i) Deficiency in laying of surface course.

(ii) Soft, yielding sub grade.

(iii) Because of oscillation of vehicles with faulty spring.

Condition :

Low : When corrugations can just be noticed with depth of valleys less than 15 mm.

Medium: When corrugations are noticed and adversely affect the use of pavement to a moderate extent with depth of valley from 15 mm to 25 mm.

High: When pronounced corrugation are evident and adversely affect the use of the pavement to a great extent with depth of valley over 25 mm.

Remedial Treatment:

Scarification and Relaying of surfacing or cutting of high spots .and filling of low spots.

7.4 Rippling/shoving

Description: Regular transverse undulation in the pavement surface consisting of closely spaced alternate valleys and crests caused generally by traffic action of moving the surface mat forward/backward or sideways. Shoving results in localised bulging of pavement surface. The first indication of shoving is formation of slippage cracks which are crescent shaped cracks.

Probable Causes: Poor material, design and construction technique/ quality control leading to unstable mix.

(ii) Lack of bond between layers combined with heavy traffic action, start-stop movement and involving negotiation of sharp curves or gradients.

Condition:

Slight - Just noticeable without much effecting riding quality.

Moderate - Roughlyride.

Severe - Very rough ride even resulting in loss of control of vehicle.

Remedial Treatment:

No action except monitoring for slight conditions. If moderate but localised; cold mix patch/hot mix patch. If more general; cold or hot mix patching after cold-planning or heater planning.

For severe condition; removal of material up to firm base and relaying a stable well-designed mix on the same may be resorted to.

7.5 Shallow Depression

There may be formation of localised shallow depressions because of presence of inadequately compacted pockets. Remedial Treatment: Filling with premix material.

7.6 Settlement

Description: Large deformation of pavement.

Probable Causes: It may have various divergent causes like' subgrade settlement, poor compaction of fill, inadequate pavement and will generally require a thorough investigation of every individual case. In urban areas settlement phenomenon is usually witnessed in the road reaches which were restored after the same were dug by utility service agency.

Remedial Treatment: Remedial treatment will generally depend on results of investigation.

7.7 Bumps or Upheavals

Description : Localised upward movement of the pavement.

Probable Causes :

(i) Unstable pavement course having been pushed or shoved by traffic.

(ii) Unstable condition in subgrade.

(iii) Frost action is cold climates.

Condition :

Low : Less than 10mm in height.

Medium : Bump height from 10mm to 25mm affecting riding quality.

High : Bump height more than 25mm affecting riding quality substantially and may be accompanied by cracks.

Remedial Treatment :

Requires investigation and adoption of measures as per investigation results. Short-term/immediate treatment : may be heater planning or cold planning or cold milling, cutting out the affected course and relaying with suitable asphalt mix material.

8.0 Disintegration

Normally maintenance intervention should commence prior to the stage of disintegration. This is the stage after severe state of distress exhibition when the pavement starts to show signs of failure and begins to fall apart.

8.1 Stripping

Description: It is condition physical separation or peeling off the bitumen film from the aggregate because of moisture. This will lead to exposure of uncoated aggregate surface and the outline of the individual aggregate particles will be visible. It is common specially to hydrophilic aggregates.

Probable Causes :

(i) Use of inadequate quantity of asphalt cement.

(ii) Use of bad quality or burnt asphalt leading to poor bond between asphalt and aggregate.

(iii) Use of hydrophilic aggregates or aggregate containing heavy dust coating.

(iv) Poor compaction.

Remedial Treatment : Avoiding use of hydrophilic aggregate, relaying affected area with fresh bituminous mix and if need be with the use of anti-stripping agents.

8.2 Loss of aggregate

Description : Appearance of rough surface with loss of aggregate in patches.

Probable Causes : Ageing and hardening of binder, brittleness of binder, insufficient quantity of binder or other deficiencies in binder leading to poor bond and inadequate compaction.

Remedial Treatment : Application of liquid seal/fog seal depending upon the extent of affected area and damage.

8.3 Ravelling/Streaking

Description : Progressive disintegration of the surface due to failure of the binder to hold the materials together. The ravelling process generally starts from the surface downwards or from edge inward. It usually begins with the blowing off of the fine aggregates leaving behind pock marks on the surface. When larger particles are broken free, the surface appears eroded. Pavement surface looks as though it is breaking up into small pieces. In streaking, this may occur in alternative lines running parallel to the pavement centreline. Ravelling can occur over the entire surface but the wheel tracks are generally the worst affected.

Probable Causes :

(i) Asphalt hardening due to ageing.

(ii) Poor quality control and poor construction technique with use of insufficient binder or brittle binder or moist aggregate.

(iii) Stripping or poor bond between asphalt cement and aggregate.

(iv) Poor compaction.

(v)Traffic action on weak and unstable surfacing course.

Condition :

Low : Noticeable loss of pavement material and appearance of light streaking lines.

Medium : Pavement disintegration in shallow patches, an open textured look and definite signs of streaking on surface of pavement.

High : Shallow disintegration of pavement surface with formation of small potholes, appearance of loose material or heavy streaking accompanied by patches of loose material.

Remedial Treatment: Application of emulsified bitumen covered with coarse sand, slurry seal or a renewal coat of premix carpet for low and medium damage. Hot mix resurfacing for severely affected sections.

8.4 Potholes

Description: Potholes are small bowl-shaped holes or depressions in the pavement surface. Usually have sharp edges and vertical sides near the top.

Probable Causes:

(i) Most pavement deteriorated while on its way to disintegration may pass through the stage of potholes. All pertinent causes for ravelling, cracking, drainage deficiency, leakage of water supply lines buried under the road etc. may ultimately lead to the formation of potholes.

(ii) Poor construction technique, use of substandard material poor quality control.

Remedial Treatment:

(i) Spraying and patching for initially affected area.

(ii) Cold mix patch or hot mix patch for medium condition.

(iii) Filling up of potholes with premix material, penetration patching plus premix material filling and surfacing for highly affected area depending upon the actual damage.

Since the treatment of potholes is a frequent requirement, the subject is treated in a slightly greater detail in Appendix to this chapter.

8.5 Edge Breaking

Description : The breaking of the pavement edge in irregular shapes. May be a terminal case for edge-cracking.

Probable Causes :

(i) Inadequate strength of pavement edges due to inadequate compaction

(ii) Poor lateral/side support from shoulders.

(iii) Infiltration of water and poor drainage. Traffic load too heavy and pavement width inadequate.

Remedial Treatment :

(i) Cutting the affected area to regular sections and rebuilding,

(ii) Attention to proper shoulder building,

(iii) Improving drainage.

8.6 The work of maintenance and repair of bituminous surfaces and provision of remedial treatment on them is required to be carried out strictly as per the provisions of the Specifications/Codes of Practice brought out by the IRC on the respective treatments so that a durable, quality work results. The relevant specifications/codes for the different bituminous courses suggested for use as remedial measure and specially the Code of Practice for Maintenance of Bituminous Surfaces (IRC:82-1982) shall therefore need to be referred to for details of carrying out the work.

8.7 These days, micro surfacing is used for sealing cracks and repairing minor pot holes. This is a cold process using polymer modified bitumen. This increase the life of the road, makes it water tight and does not raise the level of the road.

9.0 Maintenance of Cement Concrete Road

9.1 Concrete Pavements also known as Rigid Pavements have a relatively long service life, provided these are properly designed, constructed and maintained. The concrete pavements can serve upto its design service life and even beyond, if timely repairs are undertaken. All pavements deteriorated with time. The rate of deterioration of concrete pavement is comparatively much slower than the flexible pavement. In the case of concrete pavements, some distress at a few isolated locations, however, do take place immediately after or during an early stage after completion. If these isolated distresses are rectified well in time, then longer life of the concrete pavement is assured without much need of detailed periodic maintenance/rehabilitation. Preservation of concrete pavements can be broadly classified into three categories :

(i) Concrete Pavement Restoration (CPR) Techniques - Repair and maintenance operations without any overlay.

(ii) Rehabilitation - Strengthening involving overlay options.

(iii) Reconstruction - Undertaken after the end of service life or due to severe

distresses in longer stretches due to faulty design/construction.

9.2 Distress Types.

Distresses in concrete pavements are either structural or functional. Structural distresses primarily affect the pavement's ability to carry traffic load. Functional distresses mainly affect the riding quality and safety of the traffic.

9.2.1. Structural Distresses

All cracks are not structural cracks. Any uncontrolled/random crack like longitudinal, transverse, diagonal, intersecting cracks that extends through the depth of the slab (>D/2, where 'D' is depth of PQC slab) is to be considered as structural crack. Structural cracking is often caused due to excessive loading, long joint spacing, shallow or late sawing of joints, restraint at base or edge, due to joint lock-up, inadequate thickness, material related problems etc. Use of proper construction techniques and traffic load control can reduce/avoid such structural cracks. Often reasons for structural cracking could be pumping of fines from the sub-grade or the sub-base, excessive warping of the slab, subsidence of utility trench, excessive temperature stresses and moisture content. Structural cracks unless repaired effectively reduce the load carrying capacity of the pavement and adversely impact the designed service life of the pavement.

9.2.2. Functional distress

These distresses do not necessarily reduce the load carrying capacity of the pavement but affect the riding quality, and safety. Roughness, loss of surface texture or any other surface related defects, problems like faulting, scaling, ravelling and popouts etc. fall under this category.

9.3 Common Defects and Distresses in Concrete Pavements

9.3.1. Manifestation of distress in cement concrete pavements may be classified in the form of :

9.3.1.1Cracking :

(a) Plastic shrinkage cracks

(b) Crow Foot or "Y" Shaped cracks

(c) Edge cracks

(d) Corner cracks/breaks

(e) Transverse cracks

(f) Longitudinal cracks

(g) Diagonal cracks

(h) Durability “D” cracking

(i) Punchouts

9.3.1.2. Surface defects :

(a) Pop-outs/Small holes

(b) Animal/Wheel impressions

(c) Scaling

(d) Ravelling

(e) Deep abrasion/scooping of surface (following accident)

(f) Polished aggregates/glazing/smooth surface

9.3.1.3 Joint defects

(a) Spalling

(b) Sealant failure and/or loss

(c) Faulting at joints

(d) Separation at joints

9.3.1.4. Other miscellaneous defects

(a) Blowups

(b) Pumping

(c) Patch Deterioration

(d) Drop off

The broad causes for common type of defects are given hereunder in Table 10.1

Table 10.1 Types of Defects and Causes

S. No.	Class and Type of Defects	Common Causes
1.	Cracking	
	(a) Plastic Shrinkage Cracks Traffic Direction	i) Drying shrinkage stresses in surface ii) Poor curing iii) Hot windy conditions iv) Excessive water at surface (bleeding)
	(b) Longitudinal Cracks	i) Excessive drying shrinkage stresses ii) Inadequate depth of joint or late joint sawing iii) Excessive joint spacing iv) Sudden/abrupt thermal and moisture gradient changes v) Down hill paving; cracks perpendicular to the direction of super elevation vi) Channalised or static heavy loading, viz. Truck parking vii) Loss of sub-grade support, for instance poorly compacted sub grade viii) Settlement of embankment which leads to subsequent settlement of slabs ix) Different sub-base/sub-grade types having different modulus of elasticity and or moisture regime across the width of the cross-section x) "Vibrator trails" caused by malfunctioning or improper adjustment of vibrators on the paving

		machine
	(c) Transverse Cracks	i) Tensile stresses in concrete are more than tensile strength of concrete ii) Excessive drying shrinkage stresses iii) Inadequate depth and/or late initial joint groove sawing iv) Excessive joint spacing or length/width ratio of slab more than 1.5 or length of unreinforced slab exceeds normal range 4.5-6.1 m. v) Misaligned, corroded, locked, burred on ends dowel bars vi) Crack at the end of the dowel bars; or locking of dowel bars vii) Delays or interruption of concrete placing for more than 30 minutes viii) Excessive overloading ix) Sudden/abrupt thermal and moisture gradient stress changes x) Excessive sub base restraint xi) Settlement/poor sub-base support at localized area xii) Incorrect location of transverse joints at/over cross drainage structure/utility duct
	(d) Diagonal Crack	i) Excessive drying shrinkage stresses ii) Excessive thermal and moisture gradient stresses iii) Excessive joint spacing iv) Unstable sub-grade or loss of sub-base support

		(settlemet of utility trench, etc.) v) Excessive over loading vi) Frost action
	(e) Corner Breaks	i) The same as diagonal cracks ii) Poor load transfer iii) Dowel bar restraint iv) Curling, thin slabs are particularly susceptible to this cause
	(f) Aligator (Map) Cracking	i) Coarse aggregate expansion ii) Chemically reactive aggregate iii) Weak concrete iv) Improper curing
	(g) Crazing (Fine/Shallow Cracking)	i) Over finishing of surface ii) Over vibration of concrete iii) Too rich mix with poor curing and the concrete was not air entrained iv) Poor curing
	(h) Multiple Structural Cracks	i) Lack of sub-grade support ii) Excessive over loading iii) Weak concrete iv) End of service life
2.	Surface Defects	
	(a) Ravelling, Scaling	i) Segregation at surface ii) Crazing or fine alligator cracks iii) Frost iv) Unsound or dirty aggregates

		v) Weak concrete (too much water, too much fine aggregate) vi) Inappropriate curing vii) Excessive Abrasion
	(b) Popout (Small Hole),Pothole	i) Loss of contaminated or non durable concrete pockets at surface ii) Lack of homogeneity, uniformity and consistency of the mix iii) Loss of aggregate from concrete surface: thermal expansion, freeze-thaw iv) Inadequate compaction
	(c) Loss of Surface Texture, Polished Surface/Glazing/Smooth Surface	i) Movement of construction traffic at an early age ii) Wear and tear under high volumes of traffic particularly under wet or uncleaned surface iii) Poor texturing during construction iv) Soft and monomineral aggregates v) Frequent braking and turning sections vi) Non durable concrete
3.	Joint Defects	
	(a) Joint Separation	i) Insufficient or incorrect tie bar installation in longitudinal joints ii) Shoulder movement iii) Downhill slipping of slabs on a steep gradient/super elevation iv) Slippage of tie-bars at sharp curves v) high embankment/black cotton soil
	(b) Joint Seal Defects	i) Hardening (oxidation) or softening by ultra

		violet radiations ii) Stripping of joint sealant iii) Extrusion of joint sealant: overfilled groove, lack of incompressible caulking strip in bottom of groove, incorrect dimensions iv) Adhesion failure/loss of bond between walls of groove and sealant due to : inadequate preparation of groove, inadequate priming, inappropriate sealing material, semi-set/inadequately cured "cold" concrete, moisture in groove; slurry generated due to widening of groove sticking to the walls of groove v) Pressing of small stones and other incompressible matter into the sealant vi) Embrittlement of joint sealant or cohesion failure due to inappropriate sealing material, incorrect groove vii) Inadequate or no tooling to remove air bubbles viii) Inadequate curing before opening to traffic ix) Lack or absence of sealant x) Weed growth in the joints
	(c) Spalling at Cracks or Joints	i) Ingress of stones and other incompressible material into joint ii) Dynamic traffic loads at slab ends, mechanical damage iii) Weak concrete, poorly compacted or non durable, particularly at construction joints iv) Failure or defects of dowel load transfer

		system v) Joints intersection vi) Slab overstressing vii) Spalling at longitudinal joints may be due to faulty construction or cutting of joints, creating slithering or settlement of one lane
	(d) Faulting (or stepping) in Cracks or Joints	i) Along transverse joints or cracks: build up of material under the approach slab or slab piece; ingress of water internal erosion and pumping ii) Warping or curling following either moisture or temperature gradients iii) Along longitudinal joints: settlement of sub-grade or shoulder drop off caused by heavy traffic iv) Differential settlement/support due to inadequate foundation/or growth of tress roots v) Reduction in/or lack of load transfer due to separation of slabs
4.	Deformation	
	(a) Depression	i) Differential settlement or consolidation of substrate; ii) Settlement or consolidation of natural ground: compressible soils, peat pockets iii) Development of construction defects such as insufficient compaction in the foundation layers
	(b) Heave	i) Non stablished expansive soils ii) Upward movement of a slab following material build up under the slab iii) Upward thrust/pressure caused by moisture

		stresses
	(c) Bump	i) A local construction defects that me have different causes
	(d) Blow up or Buckling	i) Accumulation of incompressible material in the joints ii) Excessive expansion resulting from combined adverse thermal and moisture conditions iii) Wrong spacing of joints
	(e) Dropoff (Lane to Shoulder)	i) Wear and tear from stray and parked vehicles ii) Poor quality of shoulder material i.e. not suited for the purpose iii) Settlement of shoulder iv) Erosion of unpaved shoulder due to surface run-off in rainy season
	(f) Erosion/Undermining	i) Poor maintenance ii) Inadequate drainage/water interception provisions particularly in super elevated section
5.	Inadequate Drainage	
	(a) Pumping	i) Ingress of water through cracks and damaged joints ii) Poor or inoperational.choked sub drainage
	(b) Ponding	i) Wrong cross-section design ii) Blockage of inlets and or outlets in chute drains and collections pits
	(c) Punchout (applicable CRCP only)	i) Localised poor concrete ii) Loss of foundation support iii) Poor drainage at edge with paved shoulder

9.4 Assessment of Maintenance Needs

9.4.1 The evaluation of the existing pavement condition is the most important part of the process of assessing the maintenance needs. The maintenance strategy will be determined according to the level of deterioration. The characterization of the condition of the existing pavement largely determines the types of treatments to be considered. Characterization includes the types of distress, width and depth of crack/defect, percentage area affected; joint defects etc (refer Appendix- III).

9.4.2. The maintenance needs should be assessed every year as part of the planning of the road maintenance program. It is recommended that an overall assessment of the maintenance needs be done on the basis of condition surveys which can take various form such as:

(a) Visual rating

(b) profile/faulting/roughness measurements, by profilograph and bump integrator (BI)

(c) Deflection tests

(d) friction/skid resistance tests by sand patch

(e) Drainage condition survey

9.5 Measurement and Degree of Severity of Defects

9.5.1 The severity of any type of distress can be evaluated by the measurement of one or two parameters that best characterise that type of distress.

(a) Deformation in the pavement may be due to faulting, drop-off shoulder, heaving, blow up etc. Deformation is measured in terms of level difference in mm by using a straight edge and a graduated wedge or tape.

(b) Individual cracks can be evaluated by measuring their width in mm. This can be done by inserting metal strips of standard gauge thickness or by optical microscope. Measurements of crack length and its variation with time is also important. Cracks that run across one or more slabs are particularly severe and result from concrete tensile failure. The maximum crack width shall be recorded as representative of at least 50% of its length.

(c) Multiple and hair cracks can be evaluated by measuring the total length of cracks in mm/m^2 within a square frame with 1 m long sides.

(d) For cracks, it is also very important to know their depth, because full depth cracks (.D/2) allow ingress of water and undermine the strength of the slab and the pavement. On the other hand some kinds of shallow cracks, such as shrinkage cracks do not need to be repaired if they are isolated and short. The crack depth can be determined in cores bored from the pavement or by ultra-sonic pulse velocity measurements across the crack. The depth as determined by ultra sonic method is about 60 to 70 % of the actual depth as determined by the codes method.

(e) Surface loss (ravelling and scaling) can be evaluated by its percentage of damaged area and its maximum depth.

(f) Joint spalling can be evaluated by measuring its width in mm. The maximum spalling width shall be recorded.

(g) Individual popouts and potholes can be evaluated by measuring their diameters and depths. Multiple popouts can be evaluated by their number per square metre.

(h) Surface wearing can be evaluated by its area density as a percentage and the textural depth (sand patch test) or skid resistance of the worn surface.

(i) Patching can be evaluated as the percentage area patched to the total area of the slab.

9.6 Distress Rating System

5-level distress rating system is recommended in IRC:SP:83-2008, which is as under:

Table 10.2 Five Level Distress Rating System

Distress Rating	Slab Condition	Severity (Defects) Rating
0	Excellent	Not Discernable
1	Very Good	Minor
2	Good/Average	Moderate
3	Fair	Major
4	Poor	Extreme
5	Very Poor	Unsafe/Unserviceable

9.6.2 The severity level of the defects and distress develop during the contract defect liability period (usually specified as the first year after substantial completion) should generally not exceed degree 2

9.7 Repair Actions for different Degrees of Severity of Distress in Concrete Pavements are highlighted in Appendix-III. Detailed methodology for maintenance , repair and rehabilitation of Cement Concrete Pavements is given in IRC:SP:83-2008, which should be referred.

9.8 Maintenance of Joints

9.8.1 The overall efficiency of performance of a cement concrete pavement may be determined by the functioning of its joints. The first signs of the majority of failures will be observed at or near the joints. Proper watch and observation of joints is, therefore, of utmost importance. It is very necessary that the condition of the joint, the material in the sealant etc. are kept under careful observation.

9.8.2 The sealant material at the joint normally gets squeezed out during summer due to expansion of the slab. Subsequently as the slab contracts during the winter, the joints open up, with lowering of level and appearance of cracks in the sealant. The opening also collects dirt and extraneous material.

Therefore, the periodic maintenance of the sealant material level at the joint is important. Before doing the repair, the opened up joints are cleaned with a sharp implement and refilled with suitable joint sealant specially before the rains.

9.8.3 In the long run the filler material at the joint may get depleted or deteriorated needing renewal. In such cases the remnants of the old material are removed from the joint and replaced by fresh sealant after cleaning the when the joint opening is widest. (Guidelines furnished in IRC-57-2006 'Recommended Practice for sealing of joints in concrete pavement' and IRC : SP-83-2008- 'Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements ' may also be kept in view).

10.0 Maintenance of Drainage

10.1 It is said that poor drainage does more harm to road pavement than any other real

or imaginary causes. It is also said that failure of drains may occur more due to deficiency in its maintenance than due to defect in design or any other causes. The principal activities in the maintenance of drains may consist of

- Desilting of existing drains.
- Cleaning of weeds.
- Cleaning of obstructions, debris and blockage and
- Repair of linings immediately at the start of damages or appearance of cracks etc.

10.2 Before the on-set of monsoon all the drains shall be thoroughly de-silted. In case of pipe drains, of it is not possible to de-silt it manually, suitable mechanical devices shall be employed. Each de-silting case shall be inspected dy the Junior Engineer, at least 50% of them by the Asstt. Engineer and 25% of them by the Executive Engineer.

During the rains also a watch should be kept at the exit and entry points for water for the presence of undesirable collection of rubbish and muck etc. blocking the passage of water and in every way ensuring free unobstructed flow of rain water. The condition of road camber also needs to be watched.

10.3 All side drains require dressing and deepening before monsoon. Keeping the outfall structures and cross-drains in a state of repair is also important.

10.4 Similarly during monsoon, especially after heavy showers, all cross drainage structures shall be inspected to observe any blockage due to debris, log of wood etc. making flood water level, signs of undue scour etc. and observing needs and adequacy of existing cross drainage provision.

10.5 For observing the deficiencies in the highway pavement during rains watch should be kept to identify and preferably mark with paint, sections requiring regarding, reshaping or profile correction and the necessary corrective measures should be adopted immediately after the rains.

10.6 Some of the common deficiencies encountered in road drains and suggested remedy is as under :-

S.No.	Deficiency	Cause	Remedy
1.	Ponding	Inadequate cross-section, formation of depression or settlement in bed, bed erosion.	Deepening the drain, re-filling eroded or depressed area.
2.	Silting	Invert slope inadequate, excess soil entry into the system, less flow compared to design section	Improvement in slope if possible. Check entry points for silt rubbish etc. measures to concentrate flow to lean season. Provision of grating at entry points.
3.	Blockage due to debris vegetation etc.	Uneven drain bed, absence of maintenance, cleaning	De-silting and cleaning. Provision of grating at entry points.
4.	Erosion of bed and cross section	Steep invert slope, caving in of sides because of lack of lateral support	Provide flatter slope with drops, if needed. Adequate side support, re-alignment, if required.

11.0 Maintenance of Shoulders/Verges

11.1 Shoulders provide support and protection to road pavement and safety to road traffic. Vehicles when out of order during journey may pull over to side shoulders and keep the carriageway clear.

11.2 In order to enable the shoulder to perform its functions satisfactorily the shoulder is to be maintained in its full design width and in the original cross-slope and side slopes in embankment. The slopes may also need regular dressing to see that growth of vegetation does not impede natural drainage.

11.3 Erosion and rain cuts in shoulders and side-slopes require to be made up immediately.

11.4 The maintenance crew have to be particularly watchful to see that "the

shoulder/verge space is not lost to the road due to encroachment by shops! buildings or use as storage space.

12.0 Maintenance of Lightings and other road furniture's

12.1 The first step towards better maintenance of the road furniture is to have a comprehensive and updated inventory of the same and get a standard schedule of inspection prepared for the same. These should be got prepared, if not already there.

12.2 Regular maintenance inspection shall be carried out as per the standard schedule and special attention shall be paid to locate missing installations and place new functioning units in their place.

12.3 Regular periodical painting of installations/support structures, railing etc. shall be got done as per the schedule.

12.4 Cleaning of signboards, light installation etc. as per approved practice or as per methods prescribed by the manufacturers shall be done at the specified interval.

13.0 Norms of Maintenance

In Jan./Feb. 1993 Ministry of Surface Transport, Govt. of India constituted a Committee on norms for maintenance of roads (other than National Highways) which has submitted its report in March 1993.The 1993 maintenance norms were not based on measurable technical criteria, which reflect the desirable level of comfort, convenience and safety needed by the users. All the maintenance activities were not listed. The work norms also did not provide for adequate safety and traffic control measures. Subsequently,in 1997, a Committee was constituted to review and update the existing norms and criteria adopted for assessing the requirement of funds for maintenance of roads. The Committee submitted its report in October, 2000.The Committee recommended separate norms for urban roads. However, the various special requirements of Delhi Roads such as regular desilting of drains as more than 50% of Delhi is un-sewered, encroachment management and hoardingsetc have not been considered. Therefore, these norms when applied to urban roads must be updated for the above special requirement besides updating the same every year for the annual increase in the cost of men and material.

14.0 Important point to be observed on road inspections

Engineer-in-Chief PWD has issued comprehensive instructions on the system of road maintenance to be adopted by the field units covering scope, extent and frequency of inspection and maintenance measures and are given in appendix-II..

REFERENCES

1. Code of Practice for Maintenance of Bituminous Surfaces of Highways - IRC:82-1982.
2. IRC-57-2006 'Recommended Practice for sealing of joints in concrete pavement'
3. IRC : SP-83-2008- 'Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements.
4. IRC:SP:50-2013- " Guidelines on Urban Drainage ".

APPENDIX-I

GENERAL MAINTENANCE NORMS

1.0 Norms for Periodic Renewal

On heavily trafficked corridors (>1500 CVD) where the original specifications provided 25/40mm Asphaltic concrete (AC) periodical surface renewal may be done with 25mm AC. The life-cycle of periodical renewal for this type of surface may be taken as 7 years.

To be effective, renewal by Semi-Dense Carpet should be of a minimum thickness of 25mm. The same may be provided on BT surface with 450 to 1500 CVD traffic at 5 years interval and for corridors with traffic over 1500 CVD at 4 years interval.

2.0 Periodicity of various maintenance operations

	Operations	Periodicity
(i)	Kerb cleaning	Once a week.
(ii)	Painting of kerb stone	Quarterly
(iii)	(a) With road Marking Paint Lane marking, and marking of zebra, stop line etc.	Once in every two Months for VVIP Routes, Ring Road and NH's. Once in every three months in other master plan roads.
	(b) With Thermoplastic Paint	(i) Lanes – Once in Two Year (ii) Zebra, Arrows & Stop Line- Every Year
(iv)	Cleaning of signboards, Railing, delineator etc.	Two times in a year.
(v)	Painting of signboards, railings	Once in a year.

(vi) Pruning of trees. Twice a year.

(vii) Manuring of beds. Twice a year.

3.0 Repair/Treatment for Potholes

Several type of distresses in road pavement may finally result in the formation of potholes at some page or other. Watching out during inspection for vulnerable areas which may soon develop potholes, demarcating areas containing potholes and filling/repair of potholes, therefore, form important activities of road maintenance work.

The first principle of pothole treatment is to fill it up as soon as it is noticed since the area involved in potholes increases very fast with use of the road by traffic.

The potholes should first be drained off, if it contains water and then the surface may be allowed to dry specially when the treatment is by penetration grade bitumen or cut-back. In case of treatment with bituminous emulsion slight dampening may be helpful.

The hole should be cut to regular geometric shapes (squares and rectangles) with straight sides and vertical edges reaching upto the full affected depth. The area so shaped may go slightly beyond the actual affected area in order to have firm vertical edges resting on surface not involved in cracking etc. All loose and disintegrated material shall be removed.

If the pothole depth extends into the WBM/WMM base-course, the pothole may be filled upto the WBM base course with coarse aggregate and screening conforming to specifications of WBM/WMM (clause 404/406 of MoRTH specifications) and compacted with heavy hand-rammers or approved vibratory tampers. Alternatively, premixed WMM material conforming in a similar manner to requirements of specifications.

The remaining depth of the pothole shall then filled up with premix bituminous material conforming to open-graded premix carpet (Clause 510 of MoRTH). The filing may be done in layers not exceeding 40mm in thickness and each layer is compacted thoroughly.

Alternatively if the existing pavement surface is of superior type the filling material used may be premix dense-graded patching material of proper mix design. A small capacity portable hot mix plant may be very useful in such cases.

The laying of bituminous material course will be done after painting the sides and bottom of the affected area with a thin tacking application of hot bitumen or emulsion.

If the pothole depth lies entirely within the bituminous course itself, premix open-graded material conforming to Clause 510 or dense-graded premix material conforming to Clause 508 of MoRTH Specifications may be laid after painting the sides and bottom of the affected area with tacking application of hot bitumen or emulsion.

The bituminous material laid as above shall be compacted properly preferably by rollers, where possible, or by vibratory tampers before the mix cools below 100º C. Humping of material for compaction by traffic shall in no case be allowed.

Filling work of permanent nature should not preferably be carried out when it is raining. However, if under emergent conditions repairs are to be carried out during rains, the pot holes may be temporarily filled up with stone or brick-ballast conforming to WBM/WMM specifications (Clause 404/406 of MoRTH) using non-plastic filler and compacted thoroughly and maintained for use till such time when regular permanent repair measure is undertaken. The material so used shall be fully taken out and work redone thoroughly as per specifications during permanent repair.

In case of potholes is developed due to leakage of underground services like water mains, the area should be cut open in regular geometric shape, leakage plugged and the cut filled as per clause 404/406 of MoRTHspecifications and topped with dense graded premix material as per clause 508 of MoRTH specification. If leakage is of recurring nature then it will be preferable to provide a draining pipe also fitted to a lid kept on leaking point and draining it to the nearest storm water drains before filling & compacting the cut area as explained above.

APPENDIX-II

LIST OF IMPORTANT POINTS TO BE OBSERVED ON ROAD INSPECTION BY JES, AES EES & SES.

Inspection register to be maintained by JEs in which observations to be written LHS and action taken on RHS.

Register will be divided into three parts:

A. Daily inspection and deployment of workers.

B. Fortnightly detailed inspection.

C. Periodical Maintenance.

A. Daily Inspection :

JE/AE will take round of their jurisdiction and will deploy labour from 9 to 10 AM and ensure that :

(i) Carriage way is free from :-

(a) Pots holes.

(b) Malba/Stone grit/Diesel Oil etc.

(c) Kerb Stones, broken/damaged, bricks bats.

(d) Damaged electric pole and live wire on or near carriage way.

(e) Any other obstruction which may be a cause of accident of traffic jam.

(f) Any new encroachment in the right of way.

(g) Damaged/Defaced sign boards.

(h) Wild growth

(i) Water logging on the carriage way.

(ii) Detailed Inspection : JE should carry out detailed inspection by walk along the road at least once a week.

AE should also carry out detailed inspection by walk along the road at least once a fortnight.

EE should inspect by walk at random for some distance while on inspection.

They should check that -

(a) Day-to-Day instructions given have been followed.

(b) Dirt and dust after brooming is not being stacked over central verge or on berms.

(c) Bell mouth, outlets and drainage are cleaned in full length.

(d) There is no damaged/missing kerb stone or kerb lines.

(e) Dismantle/damaged material for example brick bats have been removed from surface/berms/central verge.

(f) White washing to kerb stones, cement railing is in order.

(g) Painting/Washing to railing sign boards have been done and they are neat and clean.

(iii) Sign Boards, railings should be cleaned/washed/painted periodically as per requirements.

(iv) Grass cutting and pruning of trees should be done periodically.

(v) Road surface cleaning, specially dirt or dust along kerb stones should be done periodically. The malba should not be put over central verge or footpath or in drains.

(vi) Road side drains/bellmouths/outlets should be cleaned twice a year to ensure proper drainage.

(vii) Water pumps should be checked at random to keep them in order for any emergency for dewatering.

(viii) Service roads should not be neglected during periodical maintenance.

(ix) Bridges, culverts, ROBs and RUBs should be checked periodically for their soundness and riding surface. Any damage noticed should be repaired/

brought to the notice to higher authorities according to its merit. Spouts should be kept out clean.

(x) Spouts of water logging should be selected and action should be taken to remove these defects as water is the enemy of the road.

Appendix-III

Table Repair Actions for Different Degrees of Severity of Distress* in Concrete Pavements

S. No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action	
					For the case d<D/2	For the case d>D/2
1.	CRACKING Single Discrete Cracks Not intersecting with any joint	w=width of crack L=length of crack d=depth of crack D=depth of slab	0	Nil, not discernible	No Action	Not applicable
			1	w<0.2mm, hair cracks		
			2	w=0.2-0.5mm, discernible from slow-moving car	Seal without delay	Seal, and stitch if L>1m
			3	w=0.5-1.5mm, discernible from fast-moving car		
			4	w=1.5-3.0mm	Seal, and stitch if L>1m	Staple or Dowel Bar Retrofit, FDR for affected portion
			5	w> 3mm.		
2.	Single Transverse (or	w=width of crack	0	Nil, not discernible	No Action	

	Diagonal) crack intersecting with one or more joints	L=length of crack d=depth of crack D=depth of slab	1	w<0.2mm, hair cracks	Route and seal with epoxy	Staple or Dowel Bar Retrofit
			2	w=0.2-0.5mm, discernible from slow vehicle		
			3	w=0.5-3.0mm, discernible from fast vehicle	Route, seal and stitch, if L>1m.	
			4	w=3.0-6.0mm	Dowel Bar Retrofit	Full Depth Repair Dismantle and reconstruct affected portion - See Para 5.5 & 9.2
			5	w> 6mm, usually associated with spalling, and/or slab rocking under traffic	Not Applicable, as it may be full depth	
3.	Single Longitudinal Crack intersecting with one or more joints	w=width of crack L=length of crack d=depth of crack D=depth of	0	Nil, not discernible	No Action	
			1	w<0.5mm, discernible from slow moving vehicle	Seal with proxy, if L>1m	Staple or dowel bar retrofit
			2	w=0.5-3.0mm, discernible from fast vehicle	Route seal and stitch, if L>1m	
			3	w=3.0-6.0 m	Staple, if L>1m	Partial Depth Repair with
			4	w=6.0-12.0mm,		

		slab		usually associated with spalling	Not Applicable, as it may be full depth	stapling
			5	w>12mm, usually associate with spalling, and/or slab rocking under traffic		Full Depth Repair Dismantle and reconstruct affected portion- See Para 5.6.4
4.	Multiple Cracks intersecting with one or more joints or cracks	w= width of crack	0	Nil, not discernible	No Action	
			1	w< 0.2mm, hair cracks	Seal, and stitch if L> 1m	Dismantle and reconstruct whole slab Reinstate sub-base, Reconstruct whole slab.
			2	w= 0.2-0.5 mm, discernible from slow vehicle		
			3	w= 0.5-3.0 mm, discernible from fast vehicle	Full depth repair	
			4	w= 3.0-6.0 mm, panel broken into 2 or 3 pieces		
			5	w> 6mm and/or panel broken into more than 4 pieces		
5.	Corner Break	w= width of	0	Nil, not	No Action	

		crack L= length of crack		discernible		
			1	W< 0.5 mm; only 1 corner broken	Seal with low viscosity epoxy to secure broken parts	Seal with epoxy seal with epoxy
			2	w< 1.5 mm; L< 0.6m, only one corner broken		
			3	w< 1.5mm; L< 0.6m, two corners broken	Partial Depth Repair	Full depth repair
			4	w> 1.5mm; L> 0.6 m or three corners broken		
			5	Three or four corners broken		Reinstate sub-base, and reconstruct the slab.
6.	Punchout (Applicable to CRCP only)	w= width of crack L= length (m/m^2)	0	Nil, not discernible		No Action
			1	w< 0.5 mm; L< $3m/m^2$	Not Applicable as Punchout is a full depth distress	Seal with low viscosity epoxy to secure broken parts
			2	Either w> 0.5 mm or L< m m/m^2		
			3	w> 1.5 mm and L< $3m/m^2$		
			4	w> 3 mm, L< 3 m/m^2 and deformation		Full depth repair-Cut out and

			5	w> 3 mm, L> 3 m/m^2 and deformation		replace damaged area taking care not to damage reinforcement
7.	**SURFACE DEFECTS** Revelling or Honeycomb type surface	r - are damaged surface/total surface of slab (%) h = maximum depth of damage			**SHORT TERM**	**LONG TERM**
			0	Nil, not discernible	No action	Not Applicable
			1	r < 2%	Local repair of areas damaged and liable to be damaged	
			2	r = 2-10 %		
			3	r = 10-25 %	Bonded Inlay, 2 or 3 slabs if affecting	
			4	r = 25-50 %		
			5	r > 50 % and h > 25 mm	Reconstruct slabs, 4 or more slabs if affecting	
8.	Scaling	r - are damaged surface/total surface of slab (%) h = maximum	0	Nil, not discernible	No action	Not
			1	r < 2%	Local repair of areas damaged and liable to be	
			2	r = 2-10 %		

		depth of damage			damaged	Applicable
			3	r = 10-20 %	Bonded Inlay	
			4	r = 20-30 %		
			5	r > 30 % and h > 25 mm	Reconstruct slab	
9.	Polished Surface/Glazing	t = texture depth, sand patch test	0		No action	Not Applicable
			1	t > 1mm		
			2	t = 1-0.6 mm	Monitor rate of deteriotion	
			3	t = 0.6-0.3 mm		
			4	t = 0.3-0.1 mm		
			5	t < 0.1 mm	Diamond Grinding if affecting 50% or more slabs in a continous stretch of minimum 5 km	
10.	Popout (Small Hole), Pothole	n = number / m^2 d= diameter h= maximum	0	d < 50mm; h < 25mm; n < 1 per 5 m^2	No action	
			1	d = 50-100 mm; h < 50 mm; n < 1 per 5 m^2	Partial depth repair 65 mm deep	
			2	d = 50-100 mm; h > 50 mm; n < 1 per 5 m^2		

		depth	3	d = 100-300 mm; h < 100 mm; n < 1 per 5 m^2	Partial depth repair 110 mm i.e. 10 mm more than the depth of the hole	Not Applicable
			4	d = 100-300 mm; h > 100 mm; n < 1 per 5 m^2		
			5	d > 300 mm; h > 100 mm; n > 1 per 5 m^2	Full depth repair	
11.	**JOINT DEFECTS** Joint Seal Defects	Loss or damage L = Length as % total joint length	0	Difficult to discern	No action	
			1	Discernible, L< 25% but of little immediate consequence with regard to ingress of water or trapping incompressible material	Clean joint, inspect later	Not Applicable
			3	Notable, L> 25% insufficient protection against ingress of water and trapping incompressible material	Clean and reapply sealant in selected locations	
			5	Severe; w > 3 mm	Clean, widen	

				negligible protection against ingress of water and trapping incompressible material	and reseal the joint.	
12.	Spalling of Joints	w = width on either side of the joint L = length of spalled portion (as % joint length)	0	Nil, not discernible	No action	Not Applicable
			1	w < 10 mm	Apply low viscosity epoxy resin/mortar in cracked portion	
			2	w = 10 -20 mm, L < 25%	do	
			3	w = 20 - 40 mm, L < 25%	Partial Depth Repair 30 - 50 mm deep, h = w + 25% of w	
			4	w = 40 - 80 mm, L < 25%	50 - 100 m deep repair. H = w + 20% of w	
			5	w > 80 mm, L > 25%		
13.	Faulting (or Steeping) in	f = difference of level	0	not discernible, 1 mm	No action.	No action.

	cracks or joints		1	f < 3 mm		
			2	f = 3 - 6 mm	Determine cause and observe, take action for diamond grinding	Replace the slab as appropriate
			3	f = 6 - 12 mm	Diamond Grinding	
			4	f = 12- 18 mm	Raise sunken slab.	
			5	f > 18 mm	Strengthen sub-grade and sub-base by grouting and raising sunken slab.	Replace the slab as appropriate
14.	Blowup or Buckling	h = vertical displacement form normal profile	0	Nil, not discernible	No action	
			1	h < 6 mm		
			2	h = 6 - 12 mm	Install Signs to Warn Traffic	Not Applicable
			3	h = 12- 25 mm	Full Depth Repair	
			4	h > 25 mm	Replace broken slabs.	
			5	Shattered slabs, i.e. 4 or more		

				pieces		
15.	Depression	h = negative vertical displacement from normal profile L= length	0	Not discernible, h < 5 mm	No action.	Not Applicable
			1	h = 5 - 15 mm		
			2	h = 15 - 30 mm, Nos < 20% joints	Install Signs to Warn Traffic	
			3	h = 30 - 50 mm		
			4	h > 50 mm or > 20% joints	Strengthen subgrade Reinstate pavement at normal level if L < 50 m.	
			5	h > 100 mm		
16.	Heave	h = positive vertical displacement from normal profile 0L= length			**SHORT TERM**	**LONG TERM**
			0	Not discernible, h < 5 mm	No action	
			1	h = 5 -15 mm	Follow up	
			2	h = 15 - 30 mm, Nos < 20 % joints	Install Signs to Warn Traffic	
			3	h = 30 - 50 mm		
			4	h > 50 mm or > 20 % joints	Stablise subgrade. Reinstate pavement at normal level if length < 20 m	
			5	h > 100 mm		scabble

17.	Bump	h = vertical displacement from normal profile	0	h < 4 mm	No action	
			1	h =4 - 7 mm	Grind, in case of new construction	Construction Limit for New Construction
			3	h = 7 - 15 mm	Grind in case of ongoing maintenance	Replace in case of new construction
			5	h > 15 mm	Full Depth Repair	Full Depth Repair
18.	Lane to Shoulder Dropoff	f = difference of level	0	Nil, not discernible < 3 mm	No action	
			1	f = 3 - 10 mm	Spot repair of shoulder	
			2	f = 10 - 25 mm	--do--	
			3	f = 25 - 50 mm	Fill up shoulder	
			4	f = 50 - 75 mm	--do--	For any 100m stretch Reconstruct shoulder, f affecting 25% or more of
			5	f > 75 mm		

						stretch
19.	**DRAINAGE** Pumping	quantity of fines and water expelled through open joints and cracks	0	Not discernible	No action	
			1 to 2	Slight/occasional Nos < 10%	Repair cracks and joints without delay	Inspect and repair subdrainage at distressed sections and upstream.
			3 to 4	Appreciable / Frequent 10 -25 %	Lift or jack slab	
			5	Abundant, crack development > 25 %	Repair distressed pavement sections. Strengthen subgrade and subbase. Replace slab.	
20.	Ponding	Ponding on slabs due to blockage of drains	0 - 2	No discernible problem.	No action.	
			3 to 4	Blockages observed in drains, but water flowing	Clean drains etc, Follow up	Action required to stop water damaging foundation
			5	Ponding, accumulation of water observed	--do--	

CHAPTER·11

UTILITY SERVICES

1.0 Introduction

1.1 The roads form a particular category of land use which utilises land for interlinking different units of areas. It provides access and approach to an area and also acts as a means of collection, dispersal and communication within the area. It may be noted that there are many other services, besides road communication, which stand in need of similar access for their linkage and may have to make their own independent arrangement of approach if part of the road land is not made available to accommodate them.

1.2 As long as these service lines do not pose a threat to the safety of the traffic or damage the road structure in any-way and they accept the primacy of the needs of the road and are committed to shift or be removed from their present location on road land when such on over-riding need arises for the road *(for* widening or other developmental priority) this co-operation in land- use between various services is considered welcome.

1.3 The above underlines the need for the following:-

(i) To lay down a safe code of procedure for construction installation of these utilities within the road land and bind all the other users of road land to this code.

(ii) To evolve a code of practice for proper restoration! reinstatement of the original arrangement when the land accommodating the utility is excavated for repair, maintenance or improvement in the installation, especially when the utility service cuts across the road and

(iii) To make the authorities owning the other utility services agree to shift at their own cost within or outside the road land when such a contingency arises because of developmental pressure on the roads.

1.4 The road land in Delhi accommodates a number of utility services belonging to other Departments like Municipal Corporation of Delhi, Delhi Jal Board, Mahanagar Telephone Nigam, Discoms (NDPL, BRPL), Delhi Development Authority, New Delhi Municipal Committee, and The Gas Authority of India Ltd. Land in Delhi being scarce and costly, it has not been possible to spare land separately for these services and the bulk of these utility services have been accommodated within the right-of-way of the master plan roads.

The services are generally housed in the development zone under the footpath and the central verge.

1.5 As a number of agencies are involved in laying and maintaining their service lines on the same road, their location and work within the right-of-way of the road require to be controlled and co-ordinated by the road owning authority, which is the PWD, for the master plan roads. It has, therefore, been felt necessary to have a common code of conduct for the different authorities. The objectives of the code of conduct will broadly be the following:-

(i) To regulate the road excavation activities of the different utility owning Departments such that service pipes conduits are laid in such a way as not to foul the future road widening.

(ii) To minimise hazard to the life of the operating personnel and the road users.

(iii) To minimise inconvenience to the traffic and other road users,

(iv) To minimise damage to the road,

(v) To prevent damage to other utility services, and

(vi) Overall to ensure a smooth and co-ordinated work programme in the interest of public convenience and road safety.

2.0 Code of Procedure

With the above in view a code of procedure has been evolved to be adhered to by all the concerned authorities. Broadly the procedure contains two sets of directives out of which one set is administrative and the other is technical in nature.

2.1 Administrative Action

2.1.1 Co-ordinated Planning

There are mainly three agencies looking after Delhi roads i.e. the erstwhile MCD (Now trifurcated into North, East & South Delhi Municipal Corporations), the NDMC and the PWD. In each of these Departments there is a Committee, which co-ordinates laying of utility services in the roads under the Department and accord road-cutting permission. In case of Delhi PWD road circles are the co-ordinating agencies for all the master plan roads in Delhi.

2.1.2 Annual Submission of Programme of Work

All the Departments owning the utility shall submit to the concerned Co-ordinating Committees by the first week of May every year, their annual programme of major works such as construction of fly-over's, sub-ways, main sewerage and water-works, programme of resurfacing of roads, programme of tree planting and of cable works involving at a stretch excavation of more than one kilometre, for all roads. The programme shall cover works to be executed from the 1st of September of that year to the end of June of the following year. While submitting the programme about the utilities the following information shall invariably be furnished.

(i) The name and type of work to be carried out,

(ii) The name of the road and the locality where it is proposed to cut the road or excavate trenches for laying the services, from the starting point to the end point.

The information shall be submitted in duplicate. The Co-ordination Committee shall then review .all these cases in the first week of July to formulate a co-ordinated plan for all these works and accord necessary sanction after taking into account the available right-of-way and the sections of the individual roads.

2.1.3 Provision of Road Crossing Pipes

The road maintenance agency will ascertain requirements of road crossing pipes from the different utilities when new roads are being constructed or existing roads are being widened.

(a) After a reference from road maintaining agency is received the utility owning unit shall indicate their final requirement of road crossing pipes within a period of 4 weeks.

(b) On receipt of this information the road maintaining agency will intimate the estimated cost of providing such cross pipes to the concerned utility/utilities which shall deposit the estimated cost within 4 weeks. Such requirement of the crossing pipes should be anticipated at least for the next 2 years, if not longer.

2.1.4 Permission by the Co-ordinating Committee

In normal circumstances, permission shall be granted after acceptance of the charges for road restoration etc. by the Department owning the utility for the full period

required to complete the work in the section. In case of any exigency the work in progress could be stopped for a specified period. The permission in deserving cases can suitably be extended.

2.1.5 Intimation to Road Maintaining Authority

In case of emergency trenching for attending to fault in existing services the concerned Division of the maintenance agency shall be intimated the exact location and extent of the road cutting and the likely duration of the trenches being kept open. On receipt of these informations the road maintaining agency will prepare a road restoration charge estimate and allow the concerned utility services to start-work on the trench. After carrying out the necessary maintenance/restoration work the Department owning the utility will make payment for the road restoration charges within 4 weeks of the receipt of the bills.

2.1.6 Information to the Traffic Police

At least 72 hours before actually taking up trenching work at site, an intimation regarding trenching on the road shall be sent to the Traffic Police authorities by the Department owning the utility to enable the police to divert and regulate traffic near the affected location. As traffic police has a representative in the Co-ordinating Committee, there is no need to obtain separate permission from the Traffic Police.

2.1.7 Information to owners of other utilities

Prior information regarding trenching works shall be sent to all other concerned Departments owning utility services at or near the location so as to enable them to take necessary steps to safeguard their underground service lines during the operation. This information shall be sent as soon as practicable and each utility seeking such information shall have its own specified central unit to receive it.

2.1.8 Revolving Fund for Restoration Charges

In order to avoid delay in making payment of road restoration charges and issue of road cutting permission a revolving fund has been created and is maintained separately with a fixed amount by the Department owning the

utility. When the road cutting permission is to be issued the utility Department is only asked to accept the bill and the money is drawn from the revolving fund. Later on the agency maintaining the revolving fund recoups the amount from the utility Department on presentation of accepted estimate.

The provision of revolving fund has been dispensed off in PWD. Now the road cutting agency has to deposit the required amount in advance before road cutting permission is issued. Only in case of emergent repairs, road is allowed to be cut subject to payment of restoration charges subsequently.

3.0 Guidelines for preparation of Road Restoration Estimates and Execution of Road Restoration works

In order to make the average field engineer aware of the existing sound engineering practices, the Indian Roads Congress have brought out a set of 'guidelines' on accommodation of underground utility services along and across roads in urban areas (IRC-98-2011). These guidelines are also helpful in having some essential measure of uniformity in preparation of road restoration estimates. It is felt that the guidelines should always be kept in view while planning a utility provision within the right-of-way of a road.

3.1 It has been suggested that for locating the utility services on a new road there should be prior consultation among the authorities owning the utilities and provision of adequate space in the road land so that the services do not interfere with one another or with the safe operation of the road.

For existing roads the proposal for new utility lines should be carefully examined to ensure that the existing service lines and future road development needs are not affected adversely nor does it lead to unnecessary expenditure.

After introduction of Trenchless Technology, various services may be laid using this technology without having to cut the road at all. PWD Engineers are advised to explore the possibility of crossing/laying of services utilising trenchless technology before granting the permission of road cutting to utility agency. **No road cutting permission is to be given on newly strengthened/constructed road, without approval of Chief Engineer.**

3.2 Keeping in mind their distinctive characteristics and in some case their inter-active nature the utility lines have been grouped as below by the IRC:-

(i) Sewer and Drainage lines

(ii) Water supply lines

(iii) Electricity cables

(iv) Telecommunication cables and Optic fibre cables

(v) Gas pipelines and those carrying combustible materials.

3.3 Sewer and drainage lines have gravitational flow and may be laid at substantial depth, requiring wider trenches during laying. Because of the presence of manholes, which get choked due to discarded materials and the possibility of overflow from these, it is preferable to avoid laying sewer lines underneath the carriageway as far as possible. However, due to limitation of ROW, sewer lines can be laid preferably at the edge of the carriageway, where ROW is more than 24m, same can be laid along both the edges of the carriageway to facilitate service connection to properties on both sides. Storm water drains may be in the form of open channels or pipelines located at the extreme edge of the right-of-way.

3.4 Water supply lines carry water under pressure and leakage may cause damage to road pavement. These lines should also not be close to sewer lines to avoid intermixing due to leakage. These are generally provided on either side of the road at a less depth.

3.5 Electricity cables should not be close to water supply lines. HT cables should not be laid in proximity to telecommunication cables and optic fibre cables because of possible electrical interference due to induced voltage. Also, all types of service lines and cables should be away from tree line to avoid possible entrapment and dislocation by tree roots. All Electrical cables shall be 1 m away from waterline.

3.6 The privatization of telecom, power, gas and other utilities has put immense pressure on urban roads. Multi utility ducts or common utility ducts are easy solutions for urban roads, excepting sewer lines all other services can be accommodated in utility ducts which criss-cross across the city and opening of road will be totally minimized.

Gas mains and other pipelines carrying combustible materials should be away from electricity cables, as they are sources of heat and should be located at extreme ends of right-of-way.

3.7 Whenever any OFC and/or any telecommunication cable agency is given permission to lay lines, it shall be by common utility duct or duct bank only. Other similar agencies can be addressed to give their plan so that all intending agencies place cables at one go. Open trenching of carriageway shall not be allowed by road authority except for sewerage lines.

3.8 Keeping in mind their distinctive requirements the IRC guidelines have recommended that the depth of laying (denoting the bottom of the trench) of the various service lines along the road as below-

(i) Trunk sewer lines - more than 1.5m.

(ii) Water supply line

Service line - 0.6 to 1m

Trunk line - 1.0 to 6 m

(iii) Electric cable

LT cable - 0.6 to 1.0 mtr

HT cable - 1.5 to 2.0 mtr

(iv) Telecommunication cables.

Directly laid - 0.6 to 1.0 mtr

Laid in ducts - 1 to 2.0 mtr

(v) Gas mains and lines - 2 to 3 mtr
Carrying combustible materials.

(vi) Distance between

Electric cables & W/S lines - Vertical - 1m

HT/LT Horizontal - 1m

(vii) Distance between - Vertical -1m

Electric cables & OFC Horizontal - 1m

3.9 When the utility service line is to cut across the road the same shall be permitted only when encased in a pipe/duct/conduit/ or culvert suitably sized and designed to accommodate the same. Such duct/culvert must extend in the entire width

of the right-of-way. No existing drainage structure shall be allowed to carry the lines across except in very special cases with specific written permission of the road Authority.

3.10 The casing pipe (or conduit pipe in the case of electric cables) carrying the utility lines, should be of steel, cast iron or reinforced cement concrete (NP-4) and large enough to permit easy withdrawal of the carrier pipe/cable. Ends of the casing shall be sealed from outside so that the annular space between the carrier and the casing does not act like a drainage path. The casing pipe may be installed preferably by boring through the road embankment. Where trenching method is adopted in exceptional cases the casing should be embedded on a 0.15 m to 0.30 metre thick layer of granular material free from rock-pieces and carefully back-filled in two stages, one upto the top of the pipe and the second upto the top of subgrade. The top of the casing pipe should be at least 1.2 metre below the road level subject to it being atleast 0.3m below the drain inverts. No longitudinal cuts shall be permitted in the main carriageway or in the portion meant for traffic for laying utility services.

3.11 In case of crossing through slab culvert the top of the slab shall be matching with the road top level.

3.12 Where the road is required to be cut in the footpath portion, no new line shall ordinarily be allowed. If an opening is made in a footpath which is 1.4m or less, in width, then the full width of the path shall be restored.

4.0 Reinstatement of Trenches

4.1 It has generally been observed that after the work of trenching and the work of installation or repair etc. of carrier/casing pipe is completed, adequate attention is not paid in carrying out the work of reinstatement of the trenches. Such narrow reinstated strips of road surface done in a poor and slip-shod manner, provides most uncomfortable riding surface and is generally a source of public criticism" Also, these patches constitute the starting points for future deterioration of the surface. Realising the importance of the subject the IRC has recently undertaken the preparation of a set of standard guidelines for reinstatement of trenches cut for accommodating utility services. It is felt that finally these guidelines, on their publication, should be followed for such work. Pending the same reinstatement work may be carried out on the

following lines.

4.2 Where the depth of fill is more than 450mm below the crust, the entire depth of cutting below the level of 450mm may be filled either with coarse sand (with fineness modulus not less than 2) or the excavated trench material of it is also of similar quality and compacted in layers of thickness not exceeding 75mm when compacted by ordinary power roller/plate compactor. For the depth upto 450mm, the construction of the entire formation width along the trench may be done with granular material. Depending upon its location and level, each layer shall be compacted as per the requirement of compaction of embankment and sub-grade (IRC:36) and that of the relevant material constituting the road crust laid down in the appropriate code of practice of the IRC. After filling the trench upto the sub-grade level, road crust in the trenches should be provided same as the of existing road crust in the adjoining reaches.

4.3 While backfilling, care shall be taken to compact the earth below the joints and cables to avoid subsidence.

4.4 Since the overall area involved is very small, it is felt possible that careful attention can be paid to the proper compaction of all the layers constituting the reinstated trench. Even then, it is expected that with time some amount of settlement may take place in this area needing the provision of a corrective patch. The corrective/replenishing patch shall be provided with suitable bituminous material matching the existing surfacing in the stretch after observing the total depth requirement, especially after monsoon. Whenever correction/ replenishment work is done the sides of the trenched area shall be cut vertical so that the material is keyed properly. The vertical sides of the existing pavement on adjacent sides shall be primed, and a tack coat provided in the bed, where necessary, to ensure proper bond between the layers.

4.5 The time-lapse between trenching and its reinstatement shall be kept to the barest minimum possible. This is considered to be an important aspect since (apart from hazards of accidents) the open trench leaves the road structure in a weak condition even when not being used by traffic.

4.6 The road maintaining Agency shall maintain a register indicating in addition to other relevant information the date of receipt of reinstatement

notice, date of commencement and completion of reinstatement work.

4.7 The utility owning unit will lay its services strictly in accordance with the permission given, adhering to the route, distance, depth etc. prescribed in the permission. In case of any violation the utility Department concerned shall dismantle the same and relay it again according to permission, at its own cost. In case of failure to do so, the road maintaining agency shall dismantle the same at the cost of the utility.

5.0. Safety Precautions before Laying and Reconstruction Operation

In order to make the laying of utilities within the right-of-way a safe operation to the utility service as well as to the road-user, certain precautions are necessary. While granting the road cutting permission the authority giving the permission has, therefore, to stipulate certain conditions which the Department owning the utility must agree to observe while making the road cut to lay the service line and again while making good the cut made. Broadly the conditions are as below:

5.1 Permission to work on the road must invariably be obtained from traffic police.

5.2 The top of the utility service shall be laid at least 1.2 metre below the road surface to provide enough cushion and save the utility from damage.

5.3 The work shall be carried out during non-peak hours and preferably at night time or in lean hours of the day for reasons of convenience and traffic safety.

5.4 Blasting for trenching will not be allowed. While making cross-cutting only half of the road/carriageway width will be cut first. The second half will be cut after the first cut is completely reinstated and restored to traffic.

5.5 Adequate number of caution boards at the specified locations and as approved by the authority issuing sanction shall be installed at site. These boards shall remain in position as long as the trench remains open.

5.6 The caution board shall be installed at both ends of the trench at least 100 metres prior to the cut. The lettering shall preferably be with luminescent paint. The board shall also contain information regarding the name of the work, date of commencement, date of completion and the name and phone number of the Engineer-in-charge of the utility service.

5.7 At night, warning red lanterns or flickering light shall be placed at both

ends of the cut at 100 metre in advance to the cut portion and red lights installed at suitable interval all along the trench. Retro reflective diversion board should also be invariably used.

5.8 The sides of the trench shall be suitably protected from collapsing if the depth of the trench is more than 0.5 metre.

5.9 Barricades consisting of good quality CGI sheets painted with red and white stripes shall be provided in the full length of the trench.

5.10 Driving of piles, poles etc. on the road crust, footpath etc. for a depth of more than 30 cm shall be avoided.

5.11 In case during the operation utility service lines of other Departments are accidentally met, the Department concerned shall be informed at once.

5.12 All the serviceable materials obtained from excavation shall be properly stacked as directed by the road maintenance authority and these shall be the property of the roads authority. All unserviceable materials shall be disposed as directed by the Roads maintaining Authority. The stacking of serviceable/unserviceable material shall be done in a manner so that it does not cause any inconvenience to the road user.

5.13 Before the work on the road cut is undertaken the Assistant Engineer-in-Charge of the road shall be informed and the work shall commence only after he is satisfied about the arrangement made.

6.0 Petrol pump on urban roads

Whenever a request is received from the oil companies like I.O.C., or H.P.L. for the construction of Petrol Pumps, following points must be kept in mind before granting the permission.

Under no circumstances the existing road alignment both horizontal & vertical, should not be allowed to be disturbed.

It must be ensured that slope of pump house platform drains away from the service road. The runoff from petrol pump station ramp should be intercepted by construction of suitable drain. The radius of entry and exit point should not be less than 30metre as per I.R.C. code 12-1983. Recommended practice for location and layout of roadside motor-fuel filling and motor- fuel filling-cum-service stations (second revision).

REFERENCES

(i) Guidelines on accommodation of utility services on Roads in urban areas - (IRC:98-2011).

(ii) Departmental instructions of PWD, Delhi Administration.

PART IV:
MISCELLANEOUS

CHAPTER-12
QUALITY CONTROL

1.0 Introduction

1.1 Quality has been defined by the ISO as "The totality of features and characteristics of a product or service that bear out its ability to satisfy stated or implied needs". Like in all other products, the most important aspect in highway construction also is its quality and the most important objective of the Supervising Department is to achieve quality in construction. The quality in this case may cover the stated or implied needs and all aspects of the construction like its size, dimensions, quantity and its ability to meet the requirements of the specifications and the agreement conditions.

1.2 All production, manufacture or construction is done with an eye to its ultimate performance and durability (life). All inputs are made keeping in view the above and the cost of achieving the above. Soon it was realised that in order to extract the best performance and durability at economical cost a certain degree of control has necessarily to be exercised on the material, specifications and the process of production or construction procedure. The three main components needing control are:-

(i) Material

(ii) Specifications and

(iii) Process or mode of construction.

1.3 The controversy has raged for long whether the point of control for achieving quality will be at the process stage or the same should simply be insisted for the end-product irrespective of the process by which it is achieved. No doubt the final quality requirement is at the end-product only. But since all processes may not be able to deliver the same end-products, the process employed should automatically become subservient to the needs of the end product and fall in line with actual requirement. Since, the durability of the quality achieved may not be apparent just when the product is ready and may manifest only with time, insistence on processes or procedures which are known to bestow

durability to the attributes of the product may not be out of place. Also, in many developing economies where work-culture or work ethics may not be of a high order, binding down the constructor to a certain minimum frame of process requirement may be essential for achieving quality.

In view of the above, in most of the highway specifications in this country, in addition to prescribing end-product quality paramenters some mandatory procedures/processes have been stipulated which may not only act as helpful guidance to the constructor but also provide some in-built assurance of quality in the product. It is felt that this combined control procedure may continue for some time.

2.0 Quality Assurance

2.1 Because of the over-riding importance of quality in any work and the fact that it will amount to a serious wastage of money and material in case the final product becomes sub-standard in quality, the modern management methods strive to adopt a fool-proof system so as to eliminate any chance of a sub-standard production. This has resulted in evolving the Quality Assurance Approach.

2.2 In terms of highway work, quality assurance may mean not to keep the quality stress confined to the limits of only a few elements like material, process etc. but to make it more broad-based and take care right from the initial approach to see that there is no question of any sub-standard production at the end of the line. Every single aspect of the work say planning, alignment, material, specification, design, procurement, personnel, construction process, equipment etc. will contain adequate safeguards and assurance that the final product will conform to the established requirement.

2.3 Quality Assurance therefore needs first of all fixing the level of quality desired at affordable cost and then to have a hard look at the entire system or procedure to make necessary changes, additions and modifications at each link in the chain to ensure that the level of quality fixed is finally achieved.

3.0 Quality Control Set-up

3.1 It has been more or less universally accepted and is logically correct also that the unit responsible for construction should be responsible for

ensuring its quality. So the direct responsibility for ensuring proper quality of work as per approved specifications for achieving the intended performance and structural, functional and aesthetical parameters, and the desired life of the building/installation/structure rests with the construction team of Executive Engineer, Assistant Engineer and Junior Engineer.

3.2 In the PWD of Government of Delhi, Quality Control work is carried out under a 3-tier set-up as under:-

(i) By the construction staff under the Engineer-in-charge,

(ii) By the Quality Assurance Team under the Superintending Engineer of the circle and comprising of Assistant Engineer (QA).

(iii) By the core cell under CE(CSQ), CPWD or through Third Party Quality Assurance agency for Major Works.

3.2.1 Primary Control

The primary testing and control or the first set of test-checks are carried out by the staff of the contractor and the Engineer-in-Charge. Ensuring execution of work to the standards and specifications as stipulated in the contract agreement is the responsibility of the construction staff headed by the Engineer-in-charge. Normally it will be the Executive Engineer under whose Division the work is being executed. It is his duty and responsibility to ensure:

(i) That all the registers of tests carried out at Construction Site or in outside laboratories , which shall be maintained by the contractor, has been issued to the contractor by Engineer-in-Charge in the same manner as being issued to PWD field staff. All samples of materials including Cement Concrete Cubes shall be taken jointly with Contractor by JE and out of this at least 50% samples shall be taken in presence of AE in charge. If there is no JE, all samples of materials including Cement Concrete Cubes shall be taken by AE jointly with Contractor. All the necessary assistance shall be provided by the contractor. Cost of sample materials is to be borne by the contractor and he shall be responsible for safe custody of samples to be tested at site.

All the test in field lab setup at construction site shall be carried out by the Engineering Staff deployed by the contractor which shall be 100% witnessed by JE and 50% of tests shall be witnessed by AE-in-charge. At least 10% of the tests are to be

witnessed by the Executive Engineer.

(ii) That the minimum number of mandatory tests as per the contract agreement have been carried out in respect of all materials and processes and the results have been found to be satisfactory so that further work can be proceeded with,

(iii) That only the materials duly approved by the competent authority have been used in the work. In respect of the locally available material the Engineer-in-charge will also approve the source (borrow area, quarry etc.) after being satisfied about their quality on the basis of results of tests carried out,

(iv) That all laboratory tests as laid down in the specifications and contract agreement are carried out at appropriate time and materials failing to conform to the same are rejected and taken away from site so that there is no chance of their use In the work,

(v) That proper records are kept about the tests conducted and results obtained and information about the result are communicated to all concerned i.e. the Quality Control Team under the circle and to the Agency when further necessary action or corrective measures are to be taken.

(vi) It will be the responsibility of the Divisional Heads as in-charge of primary quality control work to send the quarterly statement of works in progress under the tender acceptance power of Chief Engineer and above level officers, as on 31st March, 30th June, 30th September, and 31st December every year. Wherever, Third Party Quality Assurance Agency has been deployed, the same should also be reflected in the return.

3.2.2 Quality Control Team Under Work Circle

At the supervisory level there will be a Quality Control Team comprising of one Assistant Engineer (AEE or AE). The team will be directly under the charge o! the Superintending Engineer (Works). The main function of the Team is to check the compliance of Quality Assurance System by the field units, to locate the lapse/deficiency in the implementation of the Quality Assurance Plan, and to guide the field engineers in quality related aspects of the work.

In order that the role of the AE(QA) is effective in the process of Quality Assurance, the following points are essential :

(i) To fix the periodicity of visit of works in such a way that the process control at various stages is possible.

(ii) To ensure that there is minimum delay between inspection of work and communication of inspection report to the field formation.

(iii) The Assistant Engineer (QA) should carry out his tasks in a work that relates operationally to the Quality specifications and standard laid down for the work,

and to the control actions that can be applied to the construction process. Thus the Assistant Engineer (QA) should assess those aspects which are important to the overall quality of the finished work. Due to shortage of staff, there is no separate post of AE(QA) under circle office. One of the Assistant Engineer(P) may be entrusted with the charge of AE(QA) also. The following norms are suggested for inspection to be carried out by the Assistant Engineer(QA) of the circle office:

(i)	Construction works costing more than normal tender acceptance powers of the Superintending Engineer.	Each work to be inspected at least thrice during currency of work.
(ii)	Construction works costing less than the normal tender acceptance powers of the SE but more than or equal to the normal tender acceptance powers of the EE.	Each work to be inspected at least twice during currency of work.
(iii)	Construction works of the powers of EE.	Each work to be inspected once.
(iv)	Maintenance work.	Frequency to be decided by SE.

During periodical visits, efforts of the Assistant Engineer (QA) should be directed at :

(a) To check the quality of materials accepted by the field units for use in the work and to see whether the laid down system of 'Quality Assurance Plan has been followed.

(b) To check the overall quality of the finished items. Random checks shall be applied by the AE(QA) with help of handy instruments like Impact Hammer, portable penetrometer, electronic moisture meters, sand replacement method, etc.

(c) To exercise systematic scrutiny of the field test records,

(d) To provide guidance to the field staff in respect of problems relating to their field testing work,

(e) To prepare a report of inspection for SE (Construction) alongwith suggestions and recommendations, and for taking corrective measures, where required.

On receipt of the report of the Quality Assurance Team for the work under his charge, the SE is to communicate the results for corrective measures where required and the report would be sent to EE concerned by AE(QA).

3.2.3 The Core Wing for quality Assurance

The Core Wing shall have the over-all responsibility of constantly reviewing the existing quality assurance procedure, and updating them on the basis of feed back from the Quality Assurance Teams. It shall carry out the function of QA unit for works under Delhi PWD. In addition, it performs the following other functions :

(i) To carry out inspection of Original Works costing more than the SE's power of acceptance of tenders in general and maintenance works from the Quality Assurance angle on selective basis. The works where Third Party Quality Assurance agency have been engaged and detailed procedure of Quality Assurance and technical audit are followed, the works shall not be selected either for comprehensive or normal inspection.

(ii) To deal with policy issues pertaining to total Quality Management System (TQM).

(iii) To review the existing procedures regularly on the basis of feed back from the Sub Regional units, and to issue guidelines/instructions to ensure uniformity, consistency and reliability in implementation of Quality Assurance System and procedures in the Department.

(iv) To lay down norms/guidelines for periodic inspection and effective functioning of QA units.

(v) To keep itself updated with modern testing equipments and methods, and disseminate information in this regard.

(vi) To review the existing tolerance limits, and to lay down the tolerance limits in respect of finished items for which such limits are not specified.

4.0 Suggested Norms for Sharing of Test Checks

The broad functions of the three tiers constituting the quality Assurance organisation and the general responsibilities of the officers have been described in para 2 above. However, in order to keep interest in the work alive and save it from deteriorating into routine perfunctory activities, many organisations suggest a minimum specific share in the test checks to be carried out by the officers themselves. Test Checks prescribed by PWD is as under:

Field/Supervisory Level	Percentage of prescribed samples and tests to be performed
Junior Engineer	100%
Assistant Engineer	50% (100% in case JE is not available)
Executive Engineer	10%

For toning up the general standard of care and attention to testing as well as keeping the officers themselves in touch with ground realities these norms for compulsory sharing of tests may prove quite helpful. Appendix V details out the frequency of various mandatory tests required to be performed on road works prescribed by MORTH Specifications for Road and Bridge Works (Fifth Revision) 2013.

5.0 Laboratory Facilities for Testing work

5.1 Field laboratory of the Agency for construction

5.1.1 Since the agency for construction is bound by agreement to incorporate in 1ne construction only materials conforming to the prescribed quality and carryout the work as per the specified process and is primarily responsible for the over all quality of the work, he shall have his own, independent and

adequate laboratory set-up at a location approved by the Engineer. The laboratory shall be equipped with all prescribed test facility and instruments in adequate number commensurate with the load of work and staffed by a qualified Material Engineer and laboratory technicians fully conversant with the prescribed tests for the concerned highway work. Normally the specifications in the tender documents may contain a suggestive list of compulsory and optional testing equipment necessary for the work but either the absence of the same or the same not containing the test equipment specifically by name shall not be a reason for omission of the test required by the specifications. The entire laboratory set up, staff and equipment included, shall be got approved by the Engineer.

5.1.2 The Agency shall carryout all necessary tests at least to the minimum number and frequency as stipulated in the contract specifications and agreement to the satisfaction of the Engineer and submit the results to him in writing. He should inform the Departmental field staff about the time of collecting samples and conducting the tests well in advance so that they may also be associated with it.
In the absence of clear indication regarding the method and frequency of a test for any particular item the direction of the Engineer shall be final and binding.

5.1.3 For fully ensuring that the quality of the material and work conform to the required specifications, the Engineer by himself or through his authorised representatives may conduct some of the tests, within the overall specified frequency, in the agency's laboratory facility. Additional tests may also be conducted either by the Engineer or his representative or through the laboratory staff of the agency, when in the opinion of the Engineer such tests become necessary. Payment for such additional tests shall be guided by the contract conditions of individual cases.

5.1.4 The agency shall provide necessary co-operation and assistance (which may include provision of labour, attendance, assistance in packing, despatching, documenting, carriage and conveyance and any other assistance considered necessary for the testing work by the Engineer) in collecting samples and carrying out the tests as required by the Engineer from time to time.

5.2 Departmental Laboratories

5.2.1 In addition to the above, the Department needs to have its own independent laboratory set up. Consistent with the quality control set up, the Department will normally have laboratories at followinglevels:- .

i) Field Laboratory,

ii) Central Laboratory

(iii) Outside/Independent Testing Facility

5.2.2 Field laboratory at the divisional level shall be equipped with implements for collection of samples, packing, preservation and carrying out all basic routine tests of simple nature which require to be performed on the spot or for which adequate time may not be available for sending samples to Central Laboratory. They will also have adequate facility for documentation of results.

A Junior Engineer of the Division with aptitude for such testing work shall head the unit and he shall be directly under the control of the Executive Engineer. He will be a person trained by the Central Laboratory or the Regional Laboratory and preferably should have worked there for a period. However, due to shortage of staff, the concept of departmental field laboratory has been converted to contractor's field laboratory. In all major works of contract costing more than Rs. 10 crores, the contractor shall be required to establish complete field testing laboratory, and, and arrange all the relevant Codes and Standards.

A list of suggested equipment for a simple laboratory of this nature is indicated in Appendix 3 to this chapter.

5.2.3 The Central Laboratory will be the most important laboratory and is located at the headquarters of the Department under the direct control of the Core Wing. The Central Laboratory may have the following functions.

(i) These laboratories shall carry out confirmatory tests of samples collected by the AE(QA)/QA Units and also field Engineers.

(ii) This laboratory may provide training for setting up field laboratories.

A list of suggested equipment for a laboratory of this nature is shown in Appendix-1 to this chapter

5.2.4 Outside/Independent Testing Facility.

Extensive testing of the materials used for construction is a pre-requisite for attaining high quality of the work. This shall also require specialized tests, physical, chemical, ultrasonic, x-ray and various other types of tests which cannot possibly be carried out in a site laboratory. These tests also require specialized personnel who regularly deal in such testing. Therefore the need arises for carrying out the tests in outside laboratories. These laboratories may be in the Government sector, Semi Government or Private sector.

6.0 Additional quality control functions of Engineer-in- charge

6.1 It has already been mentioned that ensuring quality in the work is the primary responsibility of the Engineer-in-charge.· His control functions for quality shall, therefore, cover a few additional aspects for in-built quality assurance.

6.2 There are certain tests which are neither possible nor are required to be carried out in any of the Departmental laboratories. For control of the quality of such materials the Division shall ask the agency to furnish the manufacturer's certification to be supplied by the agency. In case of some materials whose quality deteriorates with passage of times (like cement etc.) in addition to manufacturer's certificate a few simple tests can be got conducted in the Regional/Central laboratory to test the quality of material at the time of use.

6.3 All manufactured items which are normally covered by ISI certification scheme, the ISI marking shall be insisted in addition to routine tests carried out by the Department.

6.4 For projects utilising very large amount of quarried materials occasional inspection at quarry site either by the Engineer or by his representative may be needed to be sure that the material is from the approved quarry.

6.5 For critical. works which are very sensitive to processing (compaction of difficult material, stabilization, cement concrete pavement etc.) or work involving use of sophisticated equipment, the Engineer may insist on the agency to demonstrate the work process by actual trial run on a separate stretch and observe and fix the time-cycle for different operations or any other modification required in the process to obtain the best quality of the product.

7.0 Training for quality assurance staff

For updating and refreshing the knowledge of the laboratory staff with the latest trends and procedures of testing, for acquainting them with new advanced equipment and their use and sometimes for simply enhancing the awareness of Departmental officers and Highway Engineers, regular training of refresher courses may be conducted by the Department for actual laboratory and field work connected with quality control, Similarly workshops and symposia may be conducted for dissemination of information regarding new tests, relevance of old test procedures and modification needed, if any, in the acceptance criteria for works,

8.0 Frequency and procedure for quality control tests

For all items of work the tests required to. be conducted, the standard procedure for the same, the frequency of tests and the method statement are contained in the detailed specifications for the work. Ministry of Road Transport & Highways Specifications for Read and Bridge works (Fifth Revision) and the IRC Special Publication 'IRC:SP-11-Handbook for quality control for construction of roads and Runways' contain detailed instructions on these aspects and the same shall be followed for all highway works. These instructions shall invariably form a part of the contract conditions for a work.

9.0 Record of Test Results

9.1 Records of test results form an important document of the project. Separate sets of these results shall be carefully preserved in the Division office in respect of each project work. These may be required to be produced before courts or Arbitration in case of dispute. The records are to be retained in prescribed proforma and shall be maintained in serially numbered (printed) registers, issued to. personnel incharge of quality control tests for works in the same manner as measurement books are issued. These registers shall be maintained by the contractor and presented with every running bill and payment to agency shall thus be conditional on some form of quality confirmation.

9.2 Various Organisations have standard proforma for recording quality control test results. For the sake of uniformity only the standard proforma shall be used.

The Ministry of Surface Transport have suggested a number of standard proforma for different items of read and bridge works circulated under Ministry's letter No. NH-III/PII/83 dated 19.4.1984. A set ether same are placed at Appendix-4 to. this chapter which may be followed with or without suitable addition or modification for specific work of the Department.

REFERENCES

(i) Handbook of Quality Control for Construction of Roads and Runways - IRC : SP : 11-1984.

(ii) Specifications for Road and Bridge Works (Fifth Revision)-2013 - Ministry of Road Transport & Highways.

(iii) Central Works Manual, 2014.

CHAPTER-13

INSPECTION OF WORKS

1.0 Introduction

Procedure laid down is not procedure implemented and the ultimate success of even the most well-intentioned rules and procedures lie in the extent of their effective implementation. A force which silently but relentlessly works towards greater and greater implementation as well as towards exposure of deficiency and lacuna in implementation is the fear of inspection. Close monitoring and frequent inspections constitute the basic quality assurance of all routine operations.

2.0 Objectives of Inspection

In view of the above, all Executive Departments invariably have an explicitly laid down system for inspection of works by various functionaries. Briefly the objectives of inspection may be as below:-

(i) The ultimate object of all inspections is to ensure that the final product is of the target quality from the point of view of the user. Since, however, most inspections of project under construction take place at initial and intermediate stage, it is not possible to assess the above at that stage.

These inspections, therefore, are kept confined to check that the tests and controls incorporated in the specifications for the work are being observed and the work is being carried out in close conformity with the approved plans, specifications and contract provisions.

(ii) To devise ways and means for necessary correction and remedial measures in case there is any deviation or departure from the approved provisions so that the final product is still of the design quality.

(iii) To assess, during the final inspection the measure of user satisfaction actually derived from the finished product,

(iv) To assess, in respect of maintenance works, that the construction work done earlier is being maintained in a state of

health so that they can render sustained service throughout the period of design life and the investment locked in the original construction is not dissipated in undue depreciation.

(v) To review if the facility constructed earlier is now able to meet the demands of new situations and form an idea of additional developmental needs.

(vi) To encourage and promote application of new methods and innovative techniques and get a feedback of their performance.

3.0 Inspection Programmes

3.1 Since the above objectives can be realised only through a systematic plan of inspection, in most countries there is a system of preparation of an annual inspection programme by the executive officers early during the commencement of the work season.

3.2 This inspection programme shall plan out an initial inspection of the project in the early period of the inception of the project, a final inspection of the project after it is completed physically and a suitable number of intervening inspections at a frequency warranted by its importance. For unimportant projects or projects with short construction life intermediate inspections may not be planned.

3.3 The total number of inspection, and the level of the inspecting officer shall depend on the importance of the project, the time available, the total cost of the project and the manpower available to the organisation for inspection.

3.4 In our country, by and large, advance planning of inspection programmes is not there. Inspection is often undertaken based *on* actual site need at short-term notice. It is felt that preparation and approval of an annual programme of inspection may be worth giving a trial.

In an ideal case the annual programme of inspections shall also broadly indicate the nature of each inspection and the depth of interaction intended in the same. The aspects to be examined and the degree of probing proposed shall be mentioned briefly. Each type of inspection depending on its timing may broadly indicate.

(i) The extent of actual field investigation (sampling, testing etc.) envisaged,

(ii) Verification from records of quantitative and qualitative checks conducted by the constructor and

(iii) An independent assessment of the preparatory/actual physical work claimed to have been done by the agency and to what extent it has been able to fulfil other contract conditions.

3.5 Each aspect of a work may not receive equal stress or coverage in each inspection. The inspection report may clearly state the proposed distribution of detailed coverage of items during various inspections. .

3.6 Inspection undertaken for specific purposes such as investigation of complaint or post-mortem tests of failure cases shall be treated separately.

4.0 Inspection report

Many Departments already possess their approved format for inspection notes. In case a specific format is available the same shall be followed. Alternatively, inspection report may be open and informal without any prescribed format.

4.1 Initial Inspection Report

An initial inspection report may be prepared for each project promptly after the award of construction contract and actual construction work being taken up in hand by the agency. It may outline and record the principal issues discussed during the pre-construction conference, if any, and draw the agency's attention towards the special features of the work. It will also lay stress on the special points requiring expedition on the part of the Agency as well as the Department to increase the tempo of work, and get over initial site difficulties.

4.2 Final Inspection Report

A final inspection report may be made for each project, preferably, in the prescribed proforma, if any, by the Department's Finance Wing. In the case of a project, executed in time without any technical deviation and frequently inspected during progress, the final inspection may just be a routine one to record physical completion at site.

4.3 Intermediate Inspection Report

Depending upon the individual circumstances and complexity of each case, decision can be taken regarding the number of intermediate inspection and rank of the officer undertaking the interim evaluation. If the total plan proposes a number of assessments the responsibility for some of them can be delegated to a subordinate officer. Also a conscious choice can be made either to opt for general inspection of all active phases or exercise detailed inspection of anyone or a few particular active phases each time in the area of maximum potential benefit or often in the most vulnerable or weak sector of the work. In each case, however, an intermediate inspection report has to be filed after necessary circulation to all concerned, as per rule.

4.4 Special Inspection for Experimental Projects

Inspection and evaluation of special experimental project work involving use of new material or technique and field validation of innovative specifications may be preceded by necessary advance preparation. Such inspections may be undertaken jointly in a group with representatives from different concerned disciplines and the total number of inspections to be undertaken, their periodicity and the format for recording the evidence have to be decided with care right at the initial stages of the project. The inspection report shall outline the special features of the operation, the associated problems, performance, need for modifications and conclusions supported by test-results, sketches, photographs etc.

5.0 Categories of Inspection

5.1 Judged by the nature of the exercise involved, inspection work can be sub-divided into the following categories:-

(i) Inspection of original work.

(ii) Inspection of maintenance work.

(iii) Inspection of needs.

Although the three categories mentioned above lay stress on different aspects of the work, these can very well be carried out concurrently and in the interest of saving time and effort the inspecting officer, by and large, shall have an eye

on all three aspects during every single inspection coverage.

The inspection may be either of a routine nature or a detailed one specially in case of structures.

5.2 Inspection of original work

All original works of construction, contract items and procured material require to be inspected in terms of the original specifications/clauses of agreement/contract provisions pursuant to which the finished product is being delivered. In such cases the yard sticks of evaluation are already clearly identified and recorded in terms of the attributes desired in the products or the services and the inspection shall underline the extent of its achievement and quality of implementation strictly guided by the same.

5.3 Inspection of maintenance work

Apart from assessing the fulfilment of the quantitative and qualitative requirements of the item of work, as in the case of original work, such inspections need to review the maintenance input actually made against the periodicity and adequacy as per the standard maintenance norms of the Department. Maintenance norms may be, for certain items, laid down in well-codified documents or sometimes they may only be traditionally known as per sound engineering practices but not recorded in black and white anywhere. For purposes of maintenance work both the categories may be considered as valid.

5.4 Inspection of needs and Deficiencies

In addition to the above the road requires to be inspected from a third angle as well. The Engineer-in-charge must at all times be well-aware of the developmental as well as maintenance needs of the road with respect to the existing as well as near-future road-users' demands which the original and maintenance input already made may not be adequate to fulfil. At a first glance many of these needs may appear to be pre-mature or ambitious, but if correctly assessed they may actually warn the authorities in good time against. complacency with existing width, capacity of structure and even mode of operation and prevent a crisis from developing tomorrow. Assessment of present inadequacy and needs of the facility shall be made objectively and accurately and

recorded and brought to the notice of the planners and authorities supported with logic. Only an inspecting officer in close touch with his road may be able to do this well.

6.0 Functions of the Inspector and Facilities for Inspection

The functions of the inspector and the facilities to be made available to the inspector shall depend on the agreed contract conditions of each individual case. In general, however, they may be as below:-

6.1 All project works during their progress and immediately after their completion shall be subject to inspection by the Engineer or his authorised representatives. As per contract conditions the agency for carrying out the work or his representatives shall be present at the work site during inspection, give access to the inspector to desired points of activity and provide every reasonable facility to inspect and find out whether the work is being performed or in case of completed work, if the same has been carried out as per the approved drawings, specifications and contract provisions. All necessary labour and equipment for such examination/inspection shall be provided by the agency and samples for test-checks, when desired, furnished to the inspector unless clearly stated otherwise in the agreement. When desired, the agency shall place before the inspector all relevant records regarding tests performed by the agency and results obtained, even if the copies of the same have earlier been furnished to the Department.

6.2 If the inspection involves excavation, uncovering or removal of any work done and additional tests over and above the mandatory number of tests as per agreement, the cost for the same may be borne by the Department when the test results and quality of material and work are found to be within specified limits. If the material or the work is found to be unsatisfactory or beyond the allowable limits of specifications the cost of excavation, uncovering, tests as well as reconstruction to specifications shall be borne by the agency. However, excavation, uncovering or removal made for the purpose of checking the thickness of constituent pavement courses shall be considered incidental to work and the same shall not be paid for separately. .

6.3 Generally, the agency is to carry out the work and attend to inspections during the normal working hours of the day unless directed otherwise by the Engineer.

When the work is carried out during night hours with permission of or at the direction of the Engineer, all facilities for lighting, access and safety shall be provided by the agency for proper observations of quality, work man ship and or tests during inspection.

6.4 Rejection of material or suspension of work by engineers during inspection shall be confirmed by him immediately in writing.

6.5 If any other unit of the Government or public or private corporation who bears in part or whole the expenditure on the project or on whose behalf a deposit work is being carried out by the Department, or who, otherwise, is empowered to inspect the work being administered by the agency sends a representative to inspect the work, he will be provided with the same facility as the authorised representative of the Department .

6.6 The presence of the Engineer or his authorised representative for inspection during the progress of a work shall not relieve the agency of the responsibility regarding quality or correctness for the work or shall not in any way prevent the material or work being rejected subsequently for being found defective as per test.

7.0 Inspection of Road Bridge Structures

Apart from constituting an important and critical link in the communication system a road bridge also represents a concentrated amount of locked investment of public money. Therefore, preventing it from deterioration or damage is also a loss prevention exercise. Since a bridge structure is an aggregation of technically complex elements, its inspection and maintenance observation need a professional approach. The Indian Roads Congress has already brought out a special manual on the subject (Manual for Highway Bridge Maintenance Inspection-IRC-SP-18-1978). The road engineer is advised to consult the document and keep in mind its directives for inspection of all bridge works. In general, it recommends inspection of bridge at least twice i.e. once before and again after monsoon and inspection of all foundation and protective work including measurement of scour depth and maximum flood level once during the monsoon and again just after it. The bearings and expansion joints are to be inspected during extreme temperature seasons and after floods. Preferably each Department may constitute a 'Bridge Inspection Cell' consisting of

knowledgeable persons on the subject. All observations and recommendations after inspection shall be duly recorded and follow-up action initiated so that the same can possibly be realised immediately and in any case before the next monsoon.

8.0 Check-lists for routine Inspection Work of Road Maintenance

While inspection undertaken on the basis of a specific reference may be very detailed, in-depth and to the point, routine inspection of general nature have to have a wider coverage and comprehensiveness about all aspects and the observation faculty must be backed by experience, maturity and deductiveness. It is certainly more difficult to observe a deficiency without knowing where to look for it. In such circumstances, a checklist for the items may be quite helpful even for the seasoned hand. A few such lists prepared for the inspection of maintenance work of different elements of the road are placed in the Appendix to this chapter. The points listed are by no means exhaustive but may be taken as suggestive only.

REFERENCES

1. Central PWD Code.
2. Manual for Highway Bridge Maintenance Inspection (IRC:SP:18- 1978),
3. Inspection of National Highways and Central Sector Bridge Works Ministry of Surface Transport Circular No.NH-VI-67(29)176 dt. 2.3.83 and No.RW/33037/1/87/NH-Stds. dt.23.9.87.

CHAPTER·14

URBAN ROAD RECORDS AND INVENTORY

1.0 Introduction

Possession of a comprehensive and up-to-date data base is an essential tool for decision making in any field of work. Generally, in the absence of such a data base the management may frequently be compelled to take only adhoc decisions regarding development as well as maintenance needs. Adequate data base helps in appreciating the needs of the entire road system and in fixing inter-se priority of needs.

Funds for development and maintenance being scarce its optimum utilisation assumes great importance and for this possession of a proper inventory of road and bridge works, their condition survey data and other records become a 'must'.

Inventory and records shall be maintained both at the Divisional level and at the Zonal level.

2.0 Divisional level inventory

The Divisional level inventory shall generally consist of maps, basic information about the roads and bridges, availability of Tools and Plants, details about labour gangs etc.

2.1 Land Record

2.1.1 The most important and essential possession in the Divisional records is the authenticated land plan for the right-of-way which is the owner's copy of the original revenue record.

This document shall be kept in the safe custody of a responsible officer not below the rank of Executive Engineer and may be required to be produced in the court in case of any dispute regarding ownership.

In general, the guidelines regarding the preparation of the landplans shall be in the lines of the instructions contained in the Ministry of Surface Transport circular No. *RW/NH/34041/3/93/S&R* dated 24.8.93 for land plan of National Highways, some salient features of which are quoted below.

2.1.2 To avoid folding of the sheet the land plan shall be drawn on a sheet of the size 594 mm x 420 mm (length x breadth) corresponding to the size A-2 of IS:696-1960.

2.1.3 Unless the scale is specified by the Local Revenue Authority for acceptance of the plans, the land plan may be prepared on existing village maps or settlement plans within scales ranging from 1 :2000 to 1 :5000.

2.1.4 The plan shall clearly demarcate the right-of-way limits of the roadland. Various structures coming within the right-of-way shall be indicated by conventional signs, symbols, numerical figures etc. Type of land or area on the boundary outside the right-of-way (such as built-up area, agricultural lands) may be suitably indicated.

2.1.5 This land plan shall bear the signature and seal of the competent authority of the revenue department. Authenticated copies of this shall be made and issued to subordinate offices for day-to-day use.

2.2 Composite Alignment Plan

2.2.1 The land-plan as above, however, will not be able to show all the details and complexities of the different elements and appurtenances of the road within the property line. In view of the above for the purposes of technical work a more comprehensive drawing containing all the technically important details of the road (including intersection details) shall be prepared in the form of a composite alignment plan in the scale of 1 :500.

2.2.2 This map shall indicate the following details:

(i) Road number and name of the road. (ii) Classification and category of the road

(iii) The starting point of the road (zero point) for identification of the section.

(iv) The carriageway width of the road.

(v) Its cross-sectional details showing the width of footpath, service road, verge, cycle-track, slow-moving vehicle track etc.

(vi) The type of surface.

(vii) The location of nallah, major drains and other cross-drainage works.

(viii) Road/Rail crossings, ROB's, Under passes etc.

(ix) Important colonies and prominent buildings on either side of the road.

2.2.3 The standard size of the sheet for the alignment plan shall be 594 mm x 420 mm. The length of the alignment accommodated in the sheet may, however, be varied taking care to see that no intersection is shown in parts in two sheets.

2.3 Strip Plans

2.3.1 Although the authenticated land plan and the composite alignment plans are invaluable assets for purposes of record, a third set of summary plans are considered to be very helpful for general acquaintance with a section and quick assessment of its present condition. These strip plans contain general information about a road section, its endowment and deficiencies and may easily become the most consulted set of plans in any active Division.

2.3.2 The strip plans of each road shall be prepared in the format shown in Appendix-I. The strip plan shall indicate the following information.

(I) Distance from zero end of the road,

(ii) Right-of-way

(Ill) Footpath width, type and height above adjacent pavement level.

(iv) Service road-width and type.

(v)Carriageway- width and type.

(vi) Cycle track- width and type.

(vii) Median width, type and height above adjacent road level, type of plants in it.

(viii) Green belts-width and type of plants.

(ix) No of trees and type of the trees.

(x)Railing on footpath-Type and height.

(xi) Railing on median-Type, height and location with reference to median edge.

(xii) Encroachments-Type and extent.

(xiii) Traffic Signages-mandatory, cautionary, Informatory, location and height above the road surface.

(XIV) Advertisement-size, location and height above road surface.

(XV) Street light- Location, type, height.

(XVI) Parking, bus-bays- Area demarcation.

(XVII) Drains-Location, type, width, depth.

(XVIII) Stretches with mastic wearing coat.

(XIX) Stretches with Thermo-plastic painting.

2.4 Surface History

Surface history of the main carriageway, service road carriageway, footpath and median shall be maintained as in Appendix-II alongwith the details of crust composition of the carriageways.

2.5 Details of stretches requiring special attention

The details of stretches requiring special attention for any particular reason (say correction/ improvement needs in horizontal, vertical alignment etc.) shall be maintained separately for each road.

2.6 Details of bridges, culverts and other structures

Details of all bridges and culverts shall be maintained road wise in the format shown at Appendix-Ill.

2.7 Records of Painting

Record of paintings of signages, road markings railing etc. shall be maintained in detail (Length/area, date of carrying out the work, cost etc.).

Details of painting carried out on each road shall be maintained separately.

2.8 Utilities and Service Lines

Details of all utilities including underground and overground service lines and their location.

3.0 Zonal Level Inventory

The zonal level inventory shall consist of basic information about the roads and bridges and other information required for prioritisation of various activities involved in the maintenance operations.

3.1 Detailed maps of the PWD Roads

All the details available in the Divisional records for item 2.1 to 2.4 shall preferably be available on a computer so that reprints and drawings to desired scale can be produced as and when required. The map should incorporate the details of all the services including the underground services.

3.2 Traffic Census Data

Details of traffic/pedestrian census data shall be recorded as per Appendix-IV.

3.3 Expenditure

Records shall be kept separately, roadwise, of all yearly expenditure on construction, strengthening and annual maintenance for each road.

3.4 Details of bridges, culverts and other structures

The zonal records shall also contain an updated copy of the details of all bridges, culverts and other structures as maintained by the Division (item 2.6) in the format as in Appendix-Ill.

3.5 The zonal office shall also maintain a history sheet of important roads and the special features of such roads..

4.0 The copy of the inventory and records shall be available to all work units and these shall be consulted and used as a tool for deciding the inter se priority of development as well as maintenance works both at the Division and the zone level.