About the Author

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As Advisor to National and State Governments, Ms Ramanathan works on significant urban planning policy reforms, on developing urban plans, and on urban design projects.

Ms Ramanathan is the recipient of several recognitions and awards for her work on urban planning and transformation, including Young Asian Leader by the Asia Society.

Ms Ramanathan has worked in leading architecture firms in the US and UK before her return to India to work on urban change. She is a BS from India, and an MS from Pratt Institute, New York.

Tender S.U.R.E. VOLUMES I & II - are the first comprehensive guidelines for design-cum-tendering of city roads in India, and include all aspects of urban roads - what's under, on, and above the roads.

Tender S.U.R.E. Guidelines have been formally endorsed by the Government of Karnataka as the design and execution standards for urban roads. The first set of Tender SURE roads in Bangalore have been designed and coordinated by Jana Urban Space.

The Tender SURE approach is transformational in three ways: brownfield urban design for roads that considers motorised and non-motorised mobility without land acquisition; integration of five core multi-agency service networks that run under the road; and overcoming the challenges of an inefficient and opaque system for execution.

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VOLUME 1

TENDER SURE

Swati Ramanathan

TENDER S.U.R.E.

SPECIFICATIONS for URBAN ROADS EXECUTION

Swati Ramanathan

2011

In the clamour created by the size and scale of urbanisation, we cannot lose sight of the fact that people don't live in abstract cities- they experience their lives in neighbourhoods, outside the homes they choose to rent or buy, in the streets where they walk or drive to drop their children off to school or get to work, at the markets where they shop for groceries. How India copes with urbanisation will ultimately be about the details.

Those Indians fortunate enough to have travelled outside the country, look with envy and awe at the pedestrian boulevards of Paris, cycling streets of Amsterdam, transport of Hong Kong, iconic skylines of New York, set against silken roads lined with shops and shoppers. However, these cities that we so admire and that create such pride among their local residents, emerged out of attention to detail in their planning and implementation.

We need to invest similarly in the details of our cities. With Tender SURE we could begin with the most critical aspect of networked infrastructure- urban roads. The half-kilometre stretch of road in front of our homes has a visible beginning and end. What is not visible is that this road is a link in a vital network- local roads, connected by collector and arterial roads, linked by ring roads, leading to the highways taking us in and out of the city. Roads are also the stage where the tableau of urban society can share space equitably- pedestrians, cyclists, hawkers, buses, motorists.

Today this vital network is completely fragmented and fractured, broken and bereft of planning, leading to ever-increasing traffic jams, potholes, and accidents.

Tender SURE tackles the cacophony of India's urban road woes- providing a systematic, disciplined way to finally address the details of design, procurement, and execution of our city roads.

TENDER S.U.R.E.

Specifications for Urban Roads Execution

2011 edition

Swati Ramanathan

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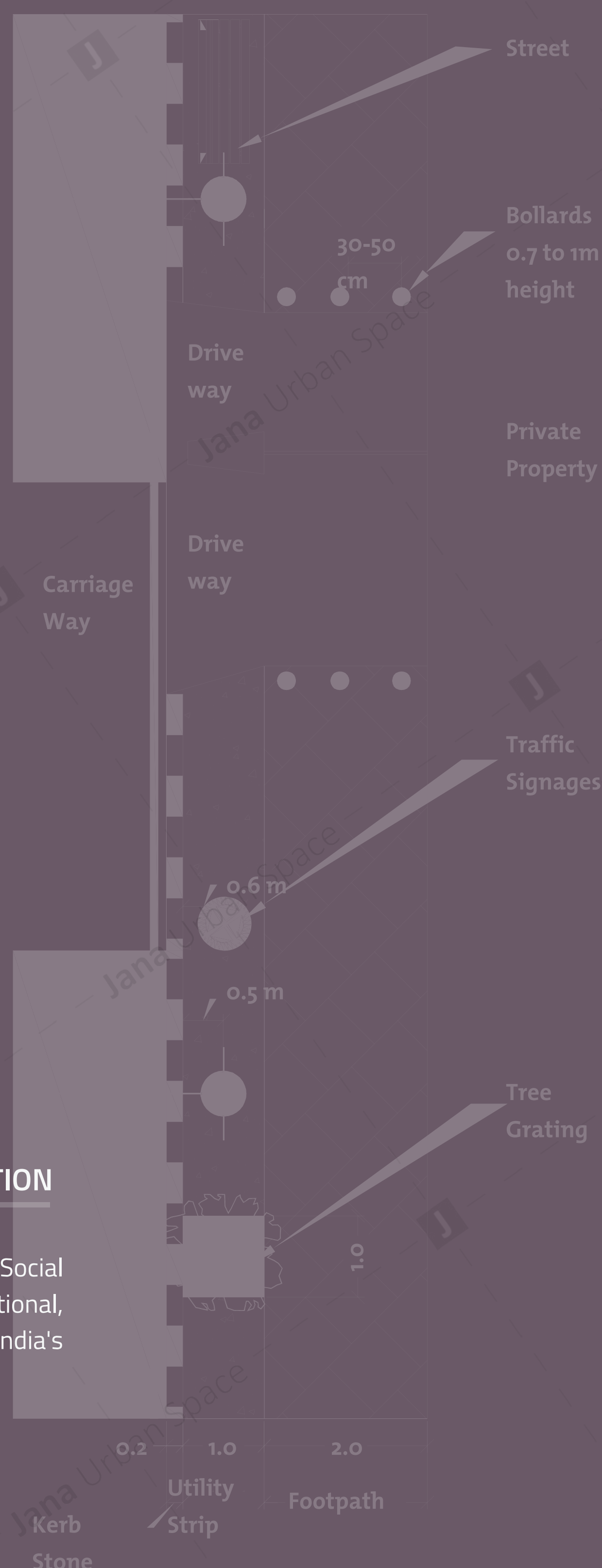
Jana USP

TENDER S.U.R.E.



ABOUT JANA URBAN SPACE FOUNDATION

Jana Urban Space is a Professional Services Social Enterprise (PSSE), delivering transformational, world-class work on the spatial dimension of India's cities.

Jana USP has four inter-disciplinary Studios -

- **Urban Planning Studio;**
- **Urban Design Studio;**
- **Spatial Mapping & Analytics Studio**
- **Architecture and Design Studio.**

The multiple studios reflect Jana USP's systems-driven approach to addressing urban Spatial challenges.

Jana Urban Space is a not-for-profit entity.

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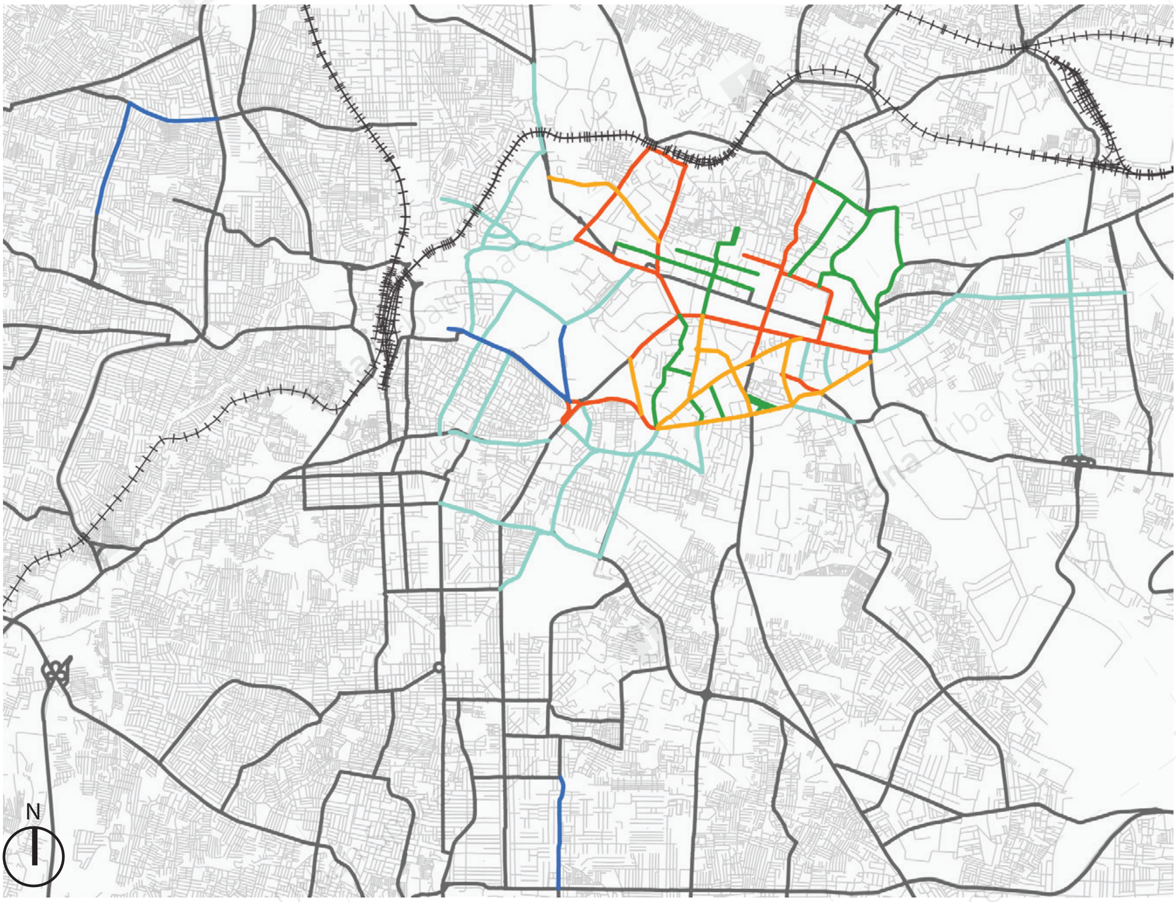
June 2011

Project Tender SURE



Legend

TS - Phase 01 (roads designed and monitored by Jana USP)	yellow
TS - Phase 02 (roads designed and monitored by BBMP)	blue
TS - Phase 03 (roads to be designed by Jana USP - Part A)	red
TS - Phase 03 (roads to be designed by Jana USP - Part B)	green
TS - Phase 03 (roads to be designed by others)	cyan

Based on the Tender S.U.R.E. Guidelines, Government of Karnataka allocated 200 crores in the 2012 budget, to redevelop key roads in Bangalore as per Tender SURE Guidelines.

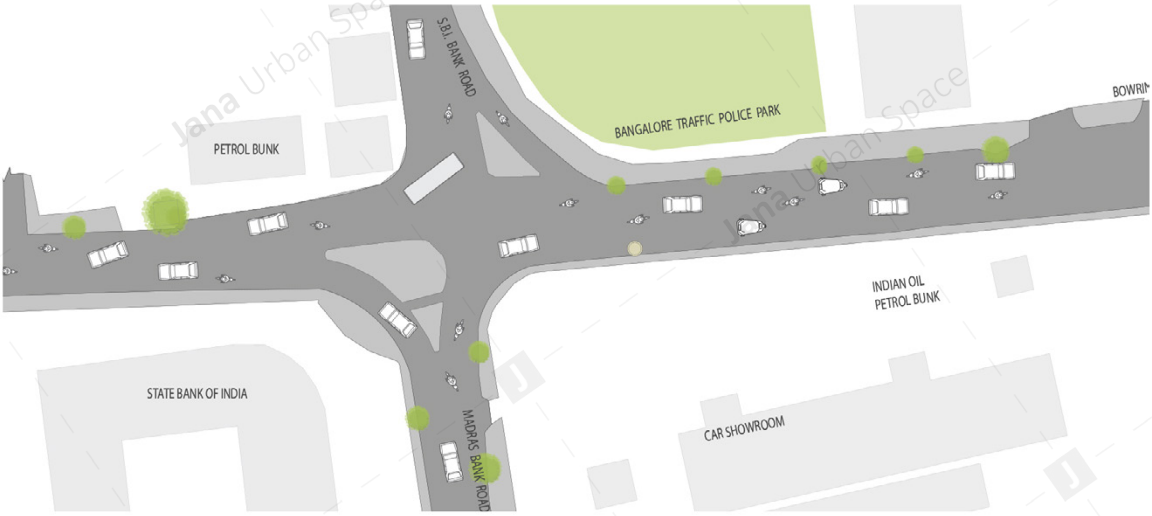
Two parallel projects are currently underway in accordance to the Tender SURE Guidelines in Bengaluru - the first set of Tender SURE roads have been awarded to RNS, for five roads to be taken up directly under the BBMP design and execuation supervision (Nrupanthunga Road, KG road, etc). The second set of seven roads are contracted out to NAPC, under the design and supervision of Jana Urban Space (St Marks Road, Cunningham Road etc).

The execution of the Tender SURE project has undergone complex challenges from inception. Many of these challenges were due to the design integration efforts needed across multiple civic agencies: this was the first time that different agencies were coming together to make joint decisions, and that too, in a time-bound manner. As a result of all this, the field and design support to the contractor to enable good execution, was unimaginably complex. The learning process was also a factor, given the pioneering nature of the project.

Based on the success of phase 01 of the project, the Chief Minister of Karnataka has announced 50 more Tender S.U.R.E roads in the 2016-2017 budget. When the list of roads was announced, residents of many areas complained about being left out of the Tender SURE project.

If public demand and political response to such demand, are considered as the ultimate test of any idea in a democracy, Tender SURE has proven its merit through this rite of passage.

Proof of Concept



St.Marks Road before Tender SURE

St.Marks Road after Tender SURE

St.Marks Road

Right-of-Way : Varies between 15M to 30M
Length: 0.9 KM
Construction Duration: March 2013 to June 2015
Contractor: Ms NAPC Pvt Ltd

Before Tender S.U.R.E *- St.Marks Road, named after the St.Marks Cathedral is part of the original British Cantonment, historically significannt to the city, and now part of the central business district of Bangalore and an important movement corridor connecting North and South. Before Tender S.U.R.E the road was plagued with poorly placed fixtures and constantly leaking pipes, pot holes travel lanes of varying widths, discontinuous footpaths, and disorganised parking creating chaotic situations for all modes of movement.*

After Tender S.U.R.E *- St.Marks Road has uniform vehicular travel lanes, each 3M wide with a shyness of 500mm on either side, allowing for smooth flow of vehicles at steady speeds and designated parking. There is a cycle track on one side of the road and safe continuous footpaths on both sides of the road. Landscape strips seaparte the non motorised movement from the vehicular travel lanes. Organised undergrouns utilities, clean geometric design, well spaced utilities, and a legible way finding system have made St.Marks Road a landmark destination for Bangalore.*

FOREWORD >>

Swati Ramanathan
Chairperson,
India Urban Space Foundation
Trustee Member,
Bangalore City Connect Foundation

Three factors have ensured the success of the automobile and 2-wheeler industry in urban India – **rising aspirations and income levels of people; expanding cities that geographically spread out work, home, schools and play; and a limited public transport network.** However, the success of this sector has snow-balled into unwelcome consequences for the quality of life and for the environment in three ways: pollution of the environment, the ever-increasing consumption of non-renewable energy, and a wrenching, everyday crisis on our urban roads.

A look back in history of India's urban settlements shows that traditional patterns of road networks responded to the use of that time - roads and lanes were used as networks for localised movement, community interaction, and thriving markets. These patterns created compact city forms and mixed-use neighbourhoods where work and home were closely located.With the advent of automobiles and the far-flung growth of the major cities, these patterns have been replaced with an equally far-flung and haphazard road network. Walking and cycling as a means of mobility, have been sidelined at an alarming rate. Individualised modes of motor transport have responded to the aspirations of an economically empowered middle class, and the failure to provide public transport alternatives.

Individualised modes of motor transport have responded to the aspirations of an economically empowered middle class, and the failure to provide public transport alternatives.

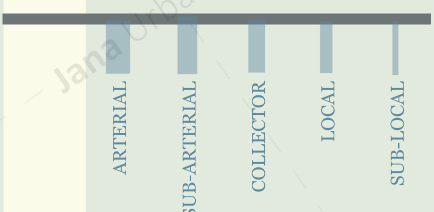
Ensuring that the benefits of motorized transport are harnessed, even as their negatives are minimized, will need many changes including public policy and behavioral changes. However, none of these will make any impact unless the actual urban road network itself becomes an enabler for these ideas, rather than an impediment, which is what they are today. Therefore, a logical starting point for any meaningful change in urban mobility, is to improve our urban road network. This critical network suffers from a **five-fold** failure in India's cities:

Why is it that we are not getting this critical network infrastructure right?

1. ***F***irst, our city roads are not planned in a clear, networked hierarchy of connectivity.
2. ***S***econd, they are not planned to integrate public transport networks: local buses, city buses, rail, and mass rapid transit.
3. ***T***hird, they do not provide a continuous network of pedestrian and cycling pathways, thereby ignoring the mobility needs of above 30% of the population.
4. ***F***ourth, they are constantly under assault by multiple agencies with no planning or coordination between each other. Network utilities beneath and above the roads – drains, telecom lines, power lines, sewage, water, electric poles, transformers – are haphazardly laid, resulting in a sense of chaos and un-usability of much of the road and footpaths.
5. ***F***ifth, they have a poor life cycle, with inadequate quality assurance on execution, and maintenance.

Rakesh Mohan, former RBI Deputy governor, describes the road policy as a vicious cycle of "build, neglect, rebuild", in the August 2011 report of the National Transport Development Policy Committee. Dr Mohan who headed the Committee, said the committee calculated the value of replacement of poor roads at a whopping 900,000 crores. While the estimations are for rural and secondary roads, urban roads are prey to the very same issues.

Tender SURE uses a system of road hierarchy with 5 types of classifications for urban roads. These are:



Despite the importance of our urban roads, why is it that we are not getting this critical network infrastructure right? Two critical gaps stand out: one, the lack of design specifications; two, poor procurement / maintenance contracts.

The pot-holes on our roads reflect the pot-holes in the process. Confusing specifications, lack of design standards and the fragmentation of works to multiple small contractors are the current norm. We see the result in the poor outcomes of road works repeatedly - cosmetic surgery that lasts for a few days and washes out in the first rain.

TENDER S.U.R.E. addresses both these gaps in the current system of city road works execution, in two volumes. The first volume contains recommendations for design standards for a range of existing road widths and intersections. Importantly, this volume also details standards for the networked utilities that are housed beneath the road surface. The second volume of Tender SURE is a Typical Contractor Agreement (TCA), intended as a guideline for the municipality in preparing road contracts and inviting requests for proposals (RFPs). The TCA aims to provide clarity of works specifications, execution, quality, contractual obligations, etc. The TCA also aims to bring in transparency in the tendering and bidding process. The TCA is expected to provide clarity to the contractors, ease the procurement issues for the municipality, aid engineers to oversee execution, and over time, build capacity for quality execution and maintenance of urban roads.

We need to make our city roads the enablers for our urban mobility ideas, rather than impediments to improvement.

There are multiple documents addressing various components of the above-some are in great detail, and others with a limited focus and hence fragmented in nature. The intent of Tender SURE is not to reinvent the wheel - after all, world-over governments are managing to build good roads in their cities. We have studied all the documents we could lay our hands on, visited road engineering and transport departments of other countries and adapted these to our local context and needs, with deliberate intent to use our own existing templates and standards where possible.

The Tender SURE Volumes pull everything together, combining broad brush with judicious detail - laying the ground for improving the quality of urban roads, and networked infrastructure.

We need to make our city roads the enablers for our urban mobility ideas, rather than impediments to improvement. If we get the design and procurement right, we can have a balanced growth of our cities, embracing development and change, even as we give local streets and neighbourhoods back to communities. Roads today are a daily source of vexation to all. Focusing on our city roads - the most critical of urban networks - Tender SURE can systematically enable urban transformation, one road at a time.





How to use Tender SURE

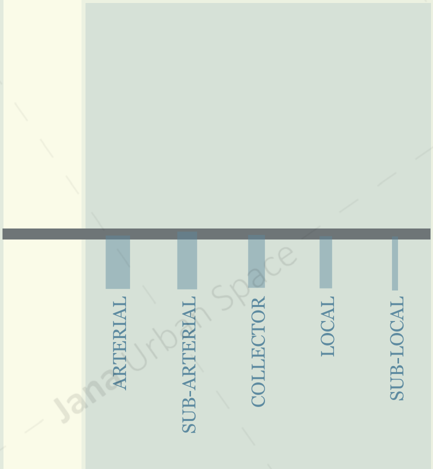
Tender Sure is divided into two documents:

1. **VOLUME I** is a reference for design standards and specifications
2. **VOLUME II** is a template of a Typical Contractor Agreement (TCA)

VOLUME I

Specifications for Urban Roads Execution, has 5 chapters.

Chapter 1 makes the case for systematic planning of the road network - especially in new extensions of existing cities and for new towns and cites – in a hierarchy of road widths based on the two primary uses: as a means of efficient access to dwellings and destination points within neighbourhoods; and as a means of mobility for all modal types and users.



Chapter 2 describes elements of the road and road intersections, providing 16 design plates for various intersection types. Particular emphasis is laid on road calming design interventions to increase safety for pedestrians and cyclists. The chapter discusses details of utilities under the road surface and street fixtures above the road.

Chapter 3 contains drawing plates for easy reference. There are two sets of plates: one for the RoW specifications; and the second for design details. While the final design for any roadwork will necessarily require factoring in actual conditions on the ground, typical plans for RoW widths between 2m to 80 m are provided in 34 RoW specification plates. The RoW design plates provide dimension standards for utilities and fixtures.

Chapter 4 provides detailed material specifications for the road surface, eliminating to a large extent, the current need for referencing multiple technical documents.

Chapter 5 estimates the life cycle costs over a twenty-year period, of implementing road works in the current manner as compared to the Tender SURE roads.

There are **7 Annexures** that include checklists for road works execution, to be used by the municipal administration and engineers, as well as local residents.

VOLUME II

Typical Contract Agreement, is aimed at eliminating ambiguity for the contractor about the technical, planning and design specifications. The current practice of references to multiple documents that require complicated searches is simplified into one single contract that contains everything.

The Typical Contract Agreement requires that contractors be provided with clear survey measurements of proposed site of road works along with the RFPs, as well as detailed drawings design and engineering specifications of work to be executed.

The TCA improves quality of delivery by aiding the following: enforcing material purchase from government-accredited list of suppliers; encouraging EPC contractors as well as smaller contractors that commit to quality execution; empaneling contractors based on technical capability; improving Quality Check(QC) guidelines, and Operations &Maintenance(O&M) requirements; ensuring integration of information between civic agencies by requiring a project plan and sign-off on the same from all concerned departments such as water and sanitation, electricity, police, public transport, before embarking on the project; and defining a participative process from the local residents for monitoring execution, in line with the guidelines of the recent National Urban Transport Policy (NUTP).

Tender SURE recommends that the same processes of survey, specifications, testing, QC and O&M, are followed by the municipality, for works executed as internal works. Tender SURE also recommends setting a cap on the percentage of total annual urban roads expenditure to be done as internal works outside of a tendering process.

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LIST OF ACRONYMS

AASHTO	American Association of State Highway Transport Officials
BBMP	Bruhat Bengaluru MahanagaraPalike
BDA	Bangalore Development Authority
BIS	Bureau of Indian Standards
BMLTA	Bangalore Metropolitan Land Transport Authority
BRTS	Bus Rapid Transit System
CBR	California Bearing Ratio
CDP	Comprehensive Development Plan
DBC	Direct Buried Cable
DULT	Directorate of Urban Land Transport
GoI	Government of India
GoK	Government of Karnataka
GSB	Granular Sub Base
HSRL	High Speed Rail Link
HYSD	High Yield Strength Deformed (steel)
IRC	Indian Road Congress
ITDP	Institute for Transportation & Development Policy
KTPP	Karnataka Transparency in Public Procurements
KBS	Karnataka Building Specification
KSRB	Karnataka Standard Rate Analysis for Buildings
KRBS	Karnataka Roads and Bridges Specification
LCC	Life Cycle Cost
LOS	Level of Service
MSA	Million Standard Axles
MRTS	Mass Rapid Transit System
MoRTH	Ministry of Road Transport and Highway
MoSRTH	Ministry of Shipping, Road Transport and Highway
NHAI	National Highway Authority of India
NMT	Non-motorised transport (pedestrians, cyclists, bullock carts, etc.)
NMV	Non-motorised vehicles (rickshaws, cyclists, bullock carts, etc.)
PHPDT	Peak Hour Peak Direction Traffic
ORR	Outer Ring Road
PWD	Public Works Department
PCU	Passenger Car Unit
R-o-W	Right of Way
ROB	Road Over Bridge
RUB	Road Under Bridge
RMC	Ready Mix Concrete
SPV	Special Purpose Vehicle
SDBC	Semi dense bituminous concrete
SWD	Storm Water Drain
SL	Street Light
SWM	Solid Waste Management
SR book	Schedule of Rates book
Tender SURE	Tender Specifications for Urban Road Execution
TMT	Thermo Mechanically Treated Steel
TPH	Total Petroleum Hydrocarbon
UR	Urban Roads
WBM	Water Bound Macadam
WMM	Wet Mix Macadam

CHAPTER 1

INTRODUCTION

tender SURE

CHAPTER 1
INTRODUCTION

INDIAN ROADS (MoRTH)

- NATIONAL HIGHWAYS (NH)
- STATE HIGHWAYS (SH)
- MAJOR DISTRICT ROADS (MDR)
- OTHER DISTRICT ROADS (ODR)
- VILLAGE ROADS (VR)

Indian roads are under 5 classifications defined by Ministry of Road Transport & Highway (MoRTH) viz, National Highways (NH), State Highways (SH), Major District Roads (MDR), Other District Roads (ODR) and Village Roads (VR). Urban roads were not part of the formal classification until the year 2002, when the Ministry of Road Transport and Highway(MoRTH) recognized that the urban roads (UR) require distinction, and began classifying urban roads separately. However, there is no clear data on the quantum and costs of urban roads since they are clubbed into an aggregate data that includes major district roads and rural roads. This aggregate accounts for 94% of the total road length as indicated in Table 1.1. Of this, 50% is paved (SASEI '05, World Bank) suggesting that this accounts for the MDR and UR. It is important to understand the share of the urban road component in order to estimate the requirements of city roads accurately. Assuming that MDR are twice the length of State Highways, this suggests that urban roads are at least a third of the total which is over a million kms in length.Given the large share of the pie, urban roads have fallen woefully short on attention of both government and market. Government has allocated miniscule infrastructure capital, and neglected the need for standards and specifications, while the infrastructure players have displayed neither innovation nor entrepreneurship.

Table 1.1>>
Road Network in India

(Source - MoRTH web, accessed Oct. 2010)

Category of road	Length in Km	%
National Highways	65,569	2
State Highways	1,30,000	4
Major Dist. Road, Rural road & Urban road	31,40,000	94
Total road network	33,40,000	

Urban Roads estimation: over a million km. in length; 33% of total roads.

1.1 >> Urban Roads

The manuals for roads currently referred to in India mainly pertain to highways and rural roads.

The manuals for roads currently referred to in India mainly pertain to highways and rural roads. The MoRTH standardized the procedure and process for building a road and published the "Specifications for Road and Bridge Works" in 1973 that got revised thrice. The latest edition is in the year 2001.This is based on a system of road classification, building and maintenance, from a time when India was predominantly rural in nature. The Indian Road Congress (IRC) has published a set of guidelines for roads, but these too do not adequately address the requirements for building and managing the ***urban*** road network.

The reality is that urban roads have been neglected thus far. No specific standards have been devised for building, space allocation, or a hierarchical classification. In contrast to rural areas, urban areas have a higher density of population and street and highway networks and visitors. The existing guidelines and road specification primarily focus on national and state highways, major district roads and village roads. Field- planners, engineers and contractors adopt these standards while implementing urban road projects, but interpret them subjectively with great variation and inconsistency.

Planned Road Development NH, SH & MDR

The economic development of the country and the consequent surge in the demand for transport services, necessitated expansion as well as improvement of the road network. This was under-taken in a planned manner at both centre and state levels.

Recognizing the need to develop arterial routes to link the Union capital with the state capitals, major seaports and other highways, the National Highways Act, 1956 was enacted. In 1957, the chief -engineers (road and bridges development) of the central and the state governments met in Bombay. Having taken into account the size of area, population, regional levels of development and future needs, the engineers presented a 20-year Road Development Plan (1961-81) in 1958 which is popularly known as the Bombay Plan.

The Plan anticipated an increase in road length from 6.10 lakh km in 1960 to 10.50 lakh km in 1981. The Plan target was to achieve a density of 32.5 km of roads per 100 sq.km. of area, 44 km for developed agricultural areas, 19 km for semi-developed and 12 km for underdeveloped areas at an estimated cost of Rs 5,200 crore, including Rs 630 crore for village roads.

The Bombay Plan set a target of 8.88 lakh km of major district roads, other district roads and classified village roads. This target was exceeded in 1978 with the construction of 9.7 lakh km of roads. The target of 98,000 km of state highways could only be achieved a decade later. Of the target of 52,000 km only 34,619 km was achieved till 1 April, 1997.

Another Road Development Plan (1981-2001), known as the Lucknow Plan of the Indian Road Congress, has made a case for 66,000 km of National Highways by 2001 A.D.

The National Transport Policy Committee, set up in 1978 under the chairmanship of B. D. Pandey, submitted its report in May 1980. It recommended 37 roads with a 12,955 km length for inclusion in the National highway network. Out of these, only 11 roads, aggregating 3,595 km length, were completed over a span of one-and-a-half decades.

The Government of India instituted an Asian Development Bank-aided study in February 1990 on Development of Long-Term Plan for Expressways in India. The study was completed in 1991 and it has recommended development of 10,020 km of expressways by 2015 at an estimated cost of Rs 58,000 crore.

– from TCI web; accessed Oct, 2010

With such a vacuum in national urban road design specifications, some states (Andhra Pradesh, Gujarat and Rajasthan), cities (Chennai, Ahmadabad) and development authorities are creating their own reference documents. A clear articulation of specifications for urban roads, will go a long way in standardizing planning and design specifications in the country.

1.2 >> Planning the Urban Road Network

Unplanned development has resulted in a random road network, with no planned hierarchy

Our cities have grown constantly over a period of time with changing boundaries. This unplanned development has resulted in a random road network. A planned approach to urban roads is the transition of the national / state / district highways, into a hierarchy of roads inside the city based on function. For example, a national / state highway cannot link to the city road network through an urban local road. It must transition into a ring road or a major arterial road of the city. The arterial road must be a trunk for sub-arterial roads, which links various collector roads. The collector roads would link neighbourhoods and transition movement from one local neighbourhood to another local neighbourhood or from a neighbourhood to a business district, through the sub-arterial / arterial network. The road network must also provide for mass public transport systems on major arterial and sub-arterial trunks, linked to air and rail stations. Collector and local roads must cater to local movement through feeder transport systems in neighbourhoods. Such a planned network of connectivity ensures **mobility** between all parts of the city.

Within neighbourhoods, providing a network of local roads that optimizes ***access*** is critical. If the only way to get to a local shopping area is through a convoluted road network, people will tend to use private vehicles. However if the network of roads provides easy travel routes that increases access, people will be more likely to walk or cycle. Access is intimately related to the block size or spacing between the local road networks.

Sub local roads provide access to individual dwellings and are not meant for through traffic. They are meant for pedestrian access in a higher density block with smaller sub-divisions. A planned network hierarchy of urban roads will define the space allocation and widths of these roads, and the allocation of land use within the network.

In India, IRC has recently revised the Engineers Pocketbook for Highway Construction to include classification and definitions of urban roads (table 1.2). The classification largely follows similar international peer documents.

UDPFI provides a similar road classification with similar widths. Both these can serve as base guidelines for new extensions or new growth centers. However existing city conditions with dense and multi-hub developments require specialised attention to include traffic management, public transit, over- and below-ground utilities, and parking. These elements are rarely factored into the planning for urban roads.

Table 1.2>>
UDPFI
Road
Classification

Classification	Width
Arterial	50 to 60m
Sub-Arterial	30 to 40m
Collector Street	20 to 30m
Local Street	10 to 20m

1.3 >> Planning Standards for Urban Roads in New Extensions

High land market values, changing land use, and increasing density have not only expanded existing towns and cities, they have also changed the existing city landscape – larger plots have been replaced with hi-rise apartments, land use has changed to include commercial businesses. Development controls have resulted in many of the old residential areas being slowly converted to commercial, retail and office developments. The streets are unable to cope with the added traffic pressure in many pockets of our cities. This densification of the urban cores has resulted in a burgeoning of traffic on the existing road network.

New extensions to cities add to the pressure on the core city roads. Invariably these new extensions are laid out without planning their integration into the existing road network, or providing intelligent zoning based on the carrying capacity of the roads. This results in new extensions that are inadequately connected to high destination nodes, and inadequately linked to the rest of the city. In addition, new extensions are often not porous in their local access between points within the neighbourhood. Hence the difference between 'as the crow flies' and what one has to actually travel on the road network between places, is often in many multiples due to poor access and lack of porosity provided by the road network. This issue of access is especially relevant for the "local" and "collector" roads linking neighbourhoods.

Two elements in planning road networks for new extensions

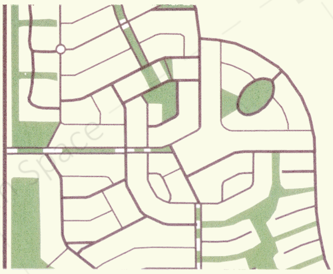
MOBILITY

ACCESS

These are the two elements in planning road networks for new extensions: **mobility** and **access**. A clear network of roads that provides easy access between places must accompany a clear hierarchy of roads for mobility. Such a network reduces the distances to travel and incentivizes walking and cycling in neighbourhoods over motor vehicles. The third element that impacts both existing and new parts of the city, is the standardized specifications for urban roads in the network. Urban roads across the city are rendered inefficient due to uneven right-of-ways, frequent intersections on major thoroughfares, unchecked parking, encroachments, etc. causing traffic bottlenecks and delays. Hence standardization of specifications for road design is the third critical element.

The road network in all new urban extensions must be designed to achieve mobility, access and standardization. However, it is only the aspect of standardization of roads that can be addressed in existing cities. This chapter focuses on the **standardization for roads**.

1.4 >> Hierarchy of Urban Roads



In determining the planning standards and execution specifications, the first step is to define the hierarchy of the road network that will determine its required usage. The hierarchy used is based on principles of planning and efficient land-use for creating an optimal connectivity. This can be modified based on the carrying capacity appropriate for the density of the city. The resulting network of streets integrates public transport, non-motorized transport and private transport.In other words, the hierarchy is based on the function that a particular road supports (in existing urban areas) or is expected to support (in new extensions).

Once the hierarchy and use are arrived at, planning the road design for the range of RoWs (Right-of-Ways) is the next step.

Urban roads are broadly organised into five categories

- ARTERIAL
- SUB-ARTERIAL
- COLLECTOR
- LOCAL
- SUB-LOCAL

a. Arterial Roads

The arterial road network should provide for uninterrupted flow of traffic radiating out of the city and serve as connectivity to major activity hubs in the city and outside to the highways. Continuity is essential and guidelines such as IRC, UDPFI recommend that arterial roads should be spaced 1.5 km apart in CBD and at 8 km in sparsely developed outskirts of the city. Although arterial network is for higher speed, the speed limits in the core city should be regulated as per the need of the land use adjacent to the road.

Arterial roads serve high trip density corridors. Significant intra-urban travel such as between central business district and outlaying residential areas, or between major suburban centers takes place on this network. Roads connecting two National Highways, State Highways, and Ring Roads would also be considered as Arterial Roads. Parking may be restricted. Pedestrian and NMT facilities need to be separated from the main traffic and grade separated crossings should be provided.

b. Sub arterial Roads

These are functionally similar to arterials with medium density traffic and lower speeds compared to arterial roads. These may have lower requirements for mass mobility and will provide greater access than arterial streets. Sub-arterial streets may be spaced at 1 to 2 km distance with spacing of intersections at 500 m distance.

c. Collector Roads

Collector roads aggregate traffic from local roads network within residential neighbourhoods, commercial roads, and industrial areas, and link this traffic to sub-arterial roads. Full access may be allowed on these streets from abutting properties. Parking restrictions may be applied during the peak hours. As collector streets connect with sub-arterial and arterial streets some of the collector streets would carry higher volumes.

d. Local Roads

These are primarily access networks for individual dwellings and residential developments. Majority of trips in urban areas either originate from or terminate on these streets. Local streets may be residential, commercial of industrial, depending on the predominant use of the adjoining land. They must allow for streamlined parking and safe and comfortable cyclist and pedestrian movement. Heavy traffic and commercial traffic is to be restricted on local roads, and adequate traffic calming measures designed for each stretch and intersection.

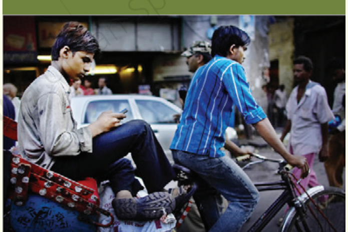
e. Sub-Local Streets / Access Streets (conservancies)

In many of the older parts of the city as well as some newly developed fringe areas, residential roads are very narrow with only 2 to 3 m wide right-of-way. These roads however form a very significant network of access to individual dwellings and pockets of dense settlements in majority of old as well as some new residential layouts.

Sub-Local Street is 2 to 5 m wide R-o-W, with shared access to pedestrian, bicycle and vehicular access to two and three wheeler traffic. R-o-W width recommended is 3 m.

In some of Bangalore's older neighborhoods such as Chamarajapete, Malleshwaram and Basavanagudi narrow lanes were reserved as conservancies and used for utilities such as drainages sewage and in recent past for electrical poles, and transformers. Over time as the original large lots have been subdivided the conservancies are being used as access roads for the property subpart facing the conservancies.

1.5 >> Right-of-way Design Specifications



*O*nce the hierarchy and use is defined, planning and designing for the range of **R-o-Ws (Right-of-Ways)** is required.

The table below indicates the primary function by the road type on two parameters: mobility and access as discussed in the previous sections. As can be seen in the table, the collector road is central for both mobility and access, linking individual neighbourhoods to the larger network of mobility in the city, while providing the access to the lower order roads that provide access within the neighbourhood.

The six key design priorities defined are marked against each road type, base on their key functional priority: pedestrians; cyclists; public transport; parking; and traffic calming measures.

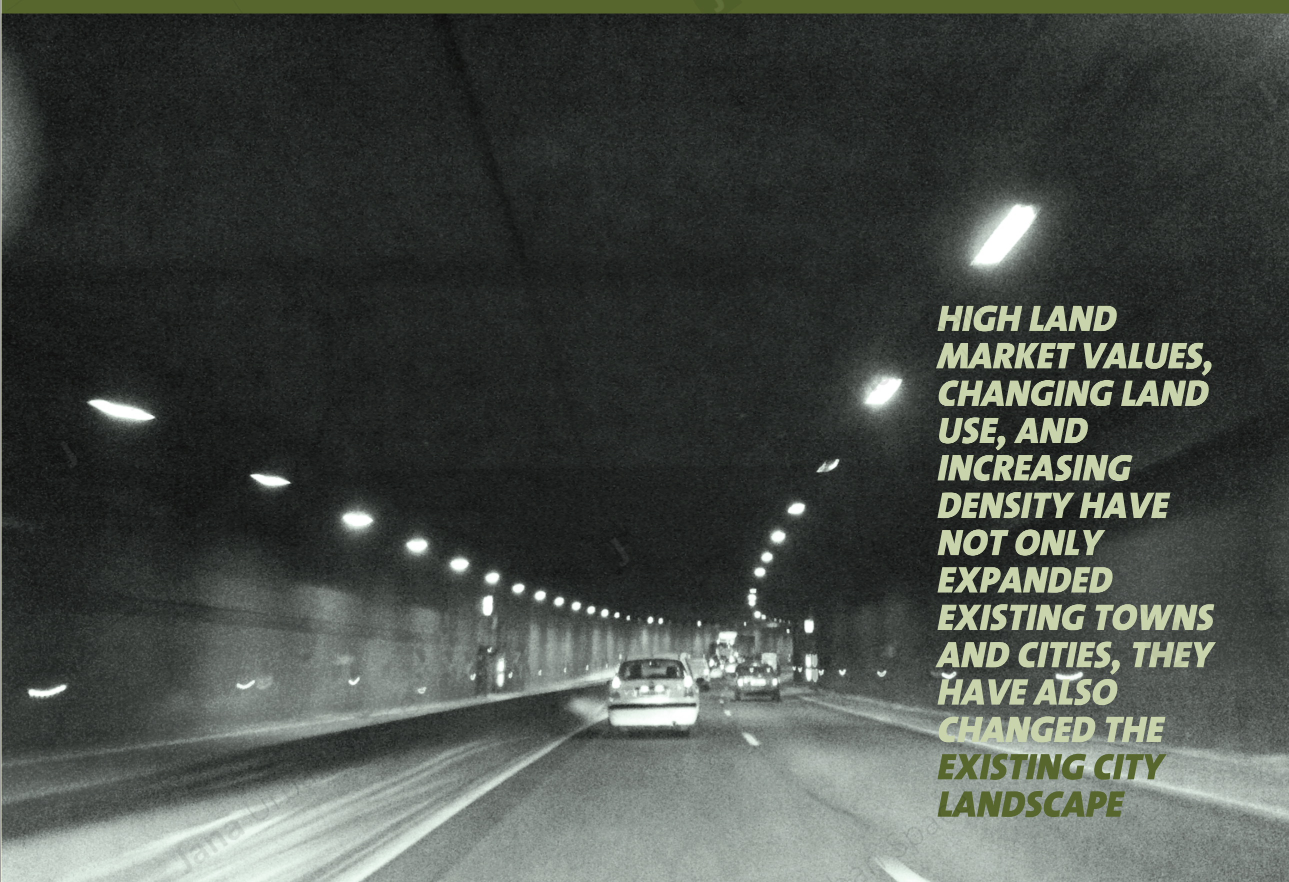
As can be seen in the table, pedestrian and cyclists are prioritised across all five road types, public transport is prioritiesd on the higher order roads namely arterial, sub-arterial, and collector. Parking is restricted on higher order roads, but may be provided for on judiciously on collector and residential streets within the neighbour-hood to facilitate residents and provide restricted parking to visitors. While maintaining traffic flow is essential in the arterial and sub-arterial networks of the city, traffic calming measures are an essential feature for safety in neighbourhoods and are indicated for collector and local streets.

These priorities are indicative and may be re-defined based on specific ground requirements.

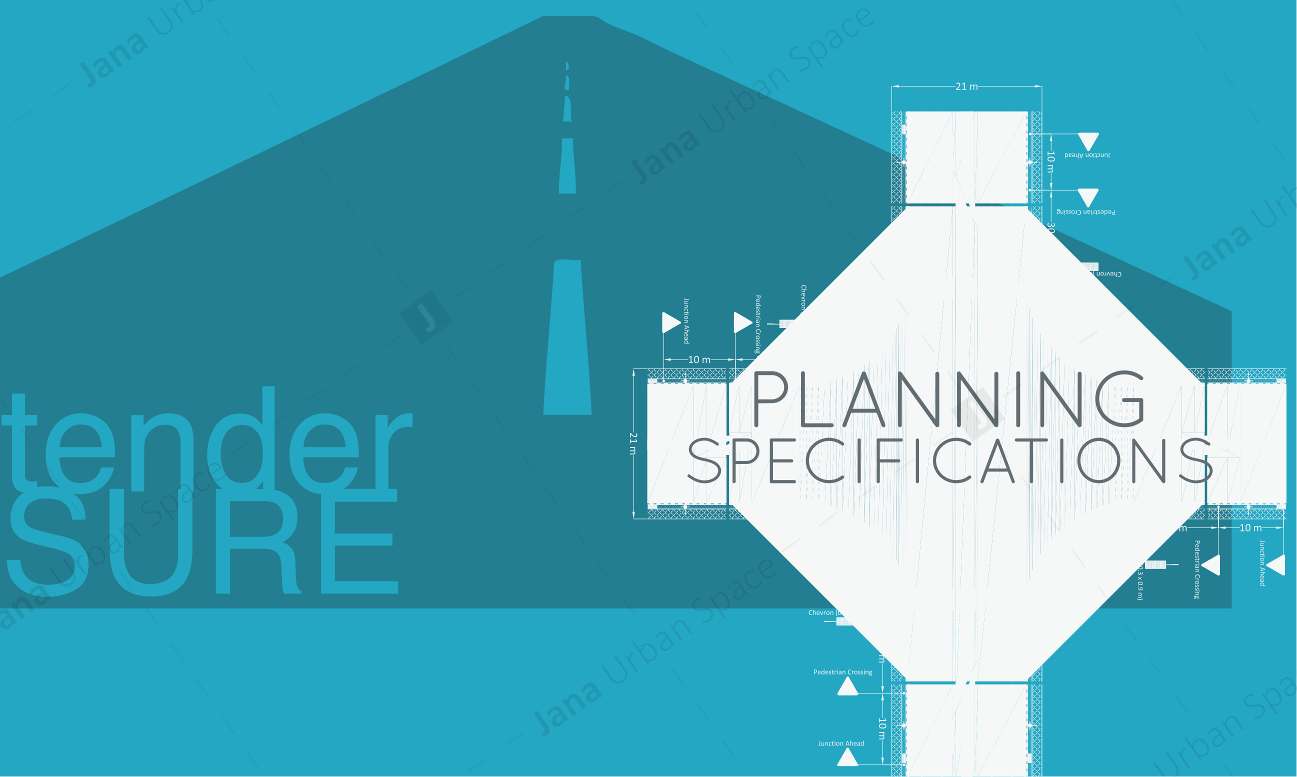
Table 1.3 >> Preference Matrix – Functionality and modes

Road Element		Road Type				
Road Element		Arterial	Sub Arterial	Collector	Local	Sub Local
Priority		Mobility		Mobility + Access	Access	
Footpath		●●	●●	●	●	Shared Path
Bicycle Path		●●	●●	●	Shared Path	
Public Transport*		●	●	●		
Parking	Bicycle		Minimal	●	●	Minimal
	2-3 wheelers		Should be avoided	●	●	Prohibited
	4 wheelers		Should be avoided	●	●	
Traffic Calming Measure				●	●	

● footpath and bicycle paths need to be adequately separated from the main travel area for safety



CHAPTER 2



PLANNING SPECIFICATIONS

CHAPTER 2
PLANNING SPECIFICATIONS

In redoing existing roads, the functional priority and design feature decisions should begin with goal setting based on stakeholder inputs (citizens, utilities and other agencies) to assess needs, limitations, and modal preferences, and analysis of adjacent land uses.

In this section various components of urban roads such as travel lanes, public transport lanes, footpath, and bicycle paths are detailed out. Other elements such as on-street parking, bus bays, loading-unloading bays, access control—entry-exit points have also been considered. In addition above grade street fixtures—streetlights, signs/signage, landscaping and below grade utility network—SW drains, sewer, electricity and telecommunication lines, and other public utility services are discussed.

2.1 >> Planning Specifications for Right-of-Way

R-o-W components

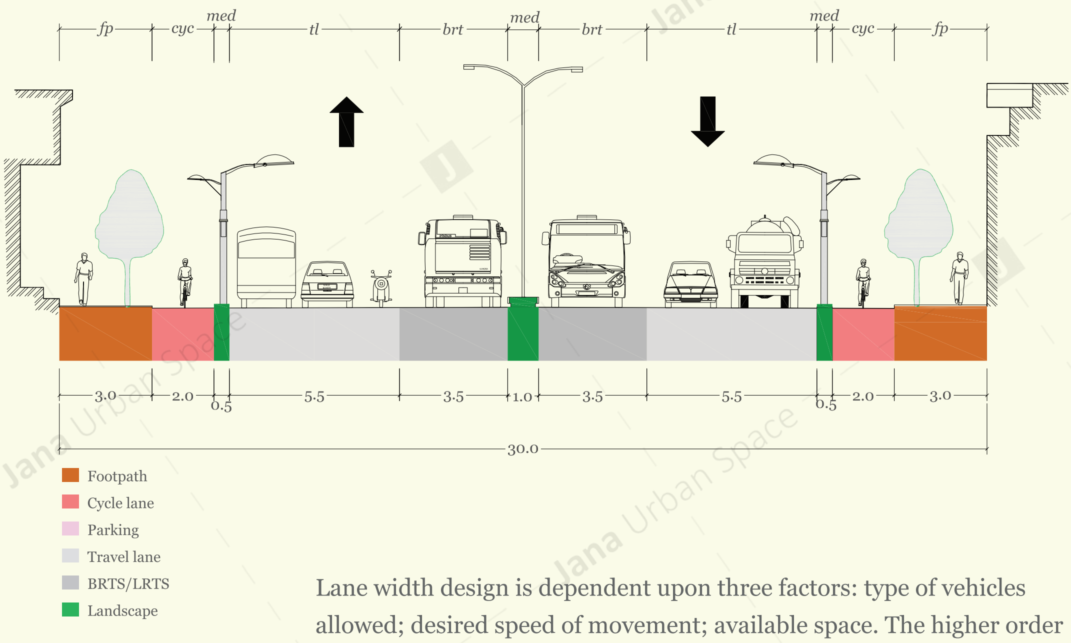
There are five elements specified in the RoW design.

1. ***F***ootpaths
2. ***C***ycle paths
3. ***M***RTS lanes
4. ***T***raffic Lanes
5. ***O***n-street parking

Traffic area includes travel lanes, medians, and turn lanes. Planted or raised medians divide the traffic in opposite directions. Right turning lanes are located by the centre/median. The traffic area can be extended into the parking/bicycle area when left running lanes need to be provided.

The key factors that governs traffic lanes are classification of road, desired speed and the expected volume of traffic .

Travel lane is the portion of the road pavement allocated to a single line movement of vehicles; it is indicated on the pavement by painted longitudinal lines or embedded markers. In the Indian context a linear management of movement appears to have limited success due to the large volumes, inadequate capacity and more importantly heterogeneous nature of vehicles mix plying the roads. Enforcement is aided by good design and the drive lanes need some standardization. In particular the road design entails a level of certainty in terms of the operational widths. The key factors that govern the width of traffic lane are classification of road, desired speed and the volume of traffic expected. Wider the lane widths, higher would be the allowable vehicular speed. A point to note, is that a travel lane will not be efficient when its width changes frequently and unexpectedly.



Lane width design is dependent upon three factors: type of vehicles allowed; desired speed of movement; available space. The higher order roads may have greater traffic lane width and the lower order roads may be restricted to the minimum lane width.Uniform lane width must be designed into all RoW planning specifications.
Range of lane width: 2.75 m- 3.7 m

Local roads and sub-local roads provide greater access and pedestrian movements. Heavy goods vehicles and trucks are not to be allowed in local and sub-local roads. Traffic calming measures are adopted in these roads. Narrower lane widths can suffice the needs of low volume/low speed residential area. For local and access roads, and places where R-o-W width varies, a uniform lane width of 2.75 m may be considered. Additional packing of space within the R-o-W should be included in the pedestrian area or landscaping area. Roads expected to have buses operating on it such as collector road, travel lane(s) must be able to accommodate bus movement (a minimum of 3 m wide lanes). On arterial and sub-arterial roads the typical lane width is 3.5 m.

Table 2.1 >>
Optimal and minimal lane widths for Urban Roads

Road Classification(Typical)	Traffic Lane Width	
	Max (M)	Min (M)
Arterial (48m)	3.50	3.00
Sub Arterial (30m)	3.50	3.00
Collector (21m)	3.50	2.75
Local (10m)	3.00	2.50

Turn lanes need to be provided near major intersections for exclusive movement of right and left turning vehicles. In such places space for the medians is used. The length of the turn needs to be calculated based on the turning traffic volume.

Level of service(LoS) of a road depends on the carrying capacity of the road, which is dependent on the efficiency of available travel lanes. If the volume of the traffic on any particular lane increases more than its carrying capacity, or the travel lane is not completely available for through traffic, that road offers poor level of service to the traffic flow. Table 2.2 highlights the relationship between speed of travel and level of service achieved for the different types of urban roads.

Table 2.2 >>
Speed of travel and LoS for Urban Roads

Road Classification (Typical)	Design Speed (kmph)	Vehicular Speed based on Level of Service (kmph)					
		A	B	C	D	E	F
Arterial (48m)	80	80	56	40	32	26.4	20
Sub Arterial (30m)	60	60	43	35	24	19.8	15
Collector (21m)	50	50	35	25	20	16.5	12.5
Local (10m)	30	30	21	15	12	9.9	7.5

2.1.1 >> Road marking

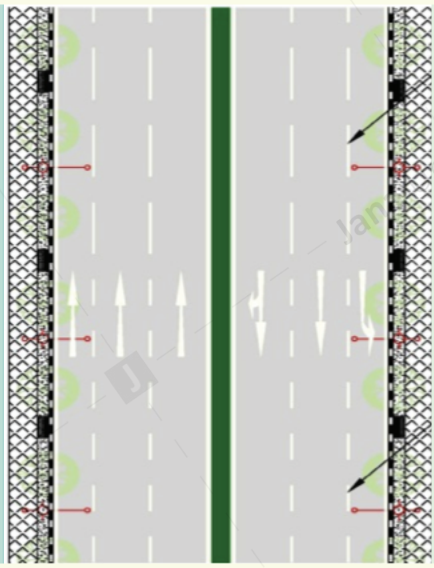
Image 2.1 >>
Two cycling lanes on one side of the road

Road Marking is critical and highly under-valued tool in Indian cities for guiding and controlling traffic on a urban roadway. The markings serve as a psychological barrier and signify the delineation of traffic path and its lateral clearance from traffic hazards for safe movement of traffic. Painted road markings have the advantage of conveying the required information to the user without distracting his/her attention from the travel lanes during poor visibility due to dust or heavy rains.

Travel lane markings in and around the vicinity of an intersection guide orderly movement of traffic around congestion points. The type of road marking used in an intersection is the function of several variables such as speed of traffic, availability of space, etc. Lane marking details are indicated in the plan drawings overleaf.

Road markings are in the shape of lines, patterns, words or devices, set into applied or attached to the carriageway or kerbs and kerb-sides.

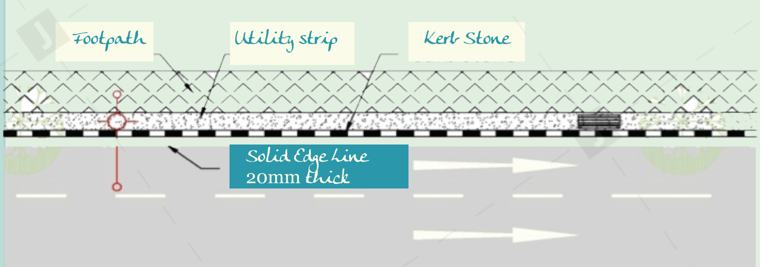
Plan view 2.2 >>
Warning
Lines



2.1.1.1 >>
Edge Line Marking

Pavement edge lines indicate the edge of the carriageway and the limit of the traffic lane. The edge line is indicated as a single continuous line placed about 15 cm from the edge. The width of the line is 15 - 20 cm.

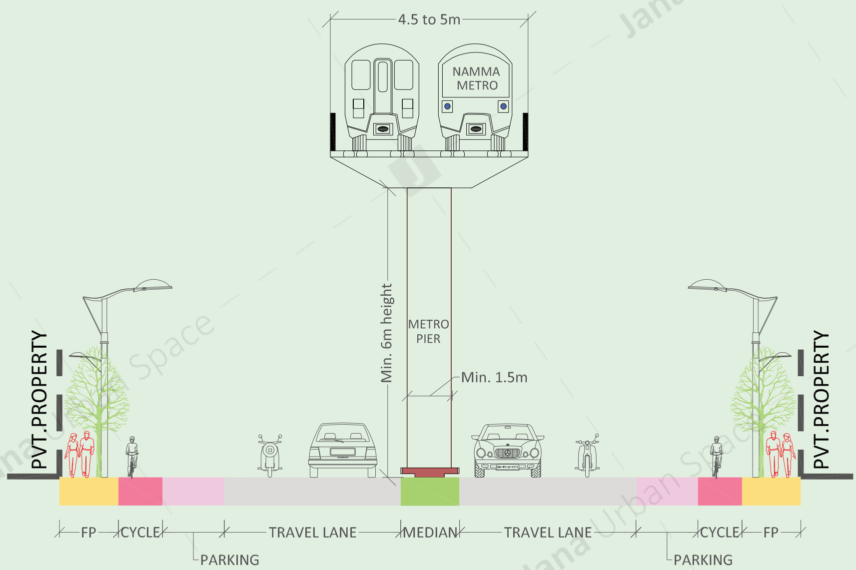
Plan View 2.3>>
Edge Line



2.2 >>
R-o-W—
Public Transport Lanes

As a general principle, provisioning for mass transit and regular public transit should be made in the planning stage in terms of space availability. The related infrastructure can be provided when required.

Due to the vehicle size and turning radius requirements, local operation is more suitable for collector roads and local. Space allocation for BRT/MRT, bus-bays is required in the design of arterial and sub-arterial streets, and bus stops at regular intervals on collector/local roads. On the roads that are designated as dedicated transit corridors, separate bus lanes need to be marked with corresponding signage. Feeder bus network should be considered on local roads, where smaller buses are more suitable.



Section View 2.4
Metro Rail piers
in the median

2.2.1 >> Mass Rapid Transit Modes

Mass rapid transit modes could be bus, light rail or heavy rail systems.
Commuter Volumes supported:
BRTS and LRTS: 8,000 phpdt
MRTS: 15,000 phpdt

Metro Rail System or **MRTS** is a passenger railway in an urban area with a high capacity and frequency, and grade separation from other traffic. Rapid transit systems are typically located either in underground tunnels or on elevated rails above street level. To build elevated rails on urban road, 9m of space is required in the centre of R-o-W, during construction. Post construction the space utilized by piers of MRT corridors provides for landscaping and recharge of ground water.

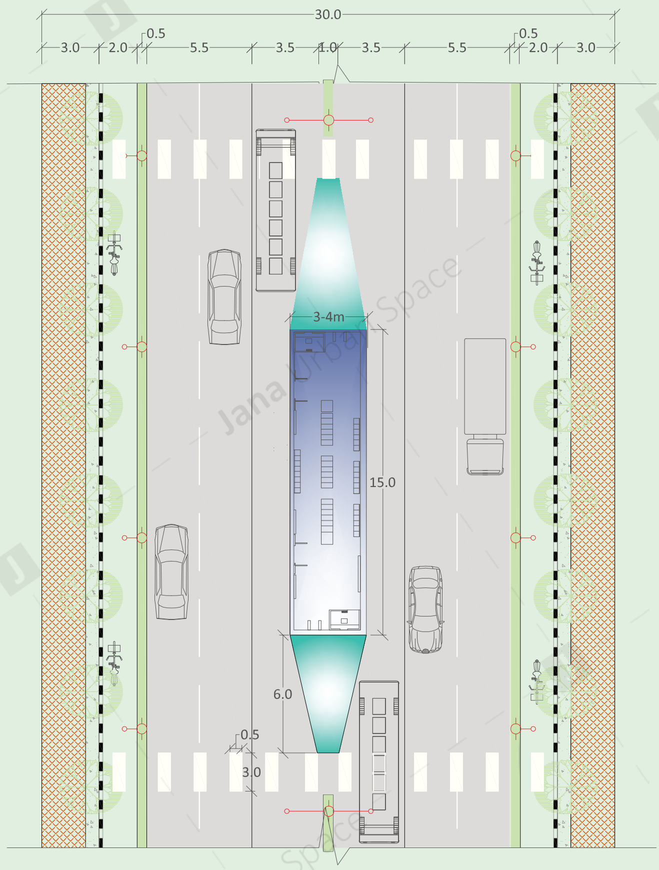
Light Rail Transit System or **LRTS** is an electric short rail system operating with single cars at grade on streets with exclusive RoW lane, below grade in subways, or above grade structures. They cater to mid to high commuter volumes.

2.2.2 >> Bus Transit

Bus Rapid Transit System or BRTS is a term applied to a rapid public transportation system using buses to provide faster, more efficient service than an ordinary bus line, but with the service quality of a rail system. Often this is achieved by making improvements to existing infrastructure, vehicles and scheduling. The goal of these systems is to approach the service quality of rail transit while still enjoying the cost savings and flexibility of bus transit.

Due to high speed achieved by this system, it is provided close to the median. Space required is 3.5 m per lane on either side of the median.

Due to high speed achieved by this system, it is provided close to the median. Space required is 3.5 m per lane on either side of the median. A station is provided at every 2 km which 3-4 m wide. Hence BRT lane width ranges from 7m on continuous section to 11 m at BRT station. Pedestrian access to the station should be provided through a raised intersection to ensure safety. Space for BRT may be provided in all sub-arterial and arterial roads. The BRT lanes provided need to be dedicated lanes without merging any other traffic.



Plan view 2.5 >> BRT Station standard dimensions

Local Bus Routes: A local bus transit operates on fixed routes and schedules and in most Indian cities is the only transit option available. Routes can be most efficient when designed in a "hub and spoke" manner with routes radiating from the Central Business District area (CBD). Sometimes they may be designed in a series of parallel routes on a grid road network.

Trunk routes operating on arterial and sub-arterial roads, and linking areas of high trip generation, may be assigned for higher bus service or BRTS. Cross city routes can be designed to link parts of the city without going into the CBD.

Bus stops: The length of the bus stop is to be determined by the

Image 2.6 >>
Unplanned bus stops in Bangalore

number of buses expected to use the stop at any given time. The bus stop should include a stable platform with a minimum width of 1.2 m and a shelter with space to incorporate related facilities such as route maps, trip planners. The bus stop area where passengers alight and embark should be clear of trees, utility poles, wires, fire hydrants.

Bus stops can be located kerb side, with extended kerbs or in bus bays. On collector roads where on-street parking is not provided, kerb side bus stops can be provided. Bus shelters for such stops should not be built on the footpaths such that they occupy the entire footpath. The minimum functional width of 1 m must be maintained for the pedestrian throughout.

Table 2.3 >>
Distance to access public transport services

The table below indicates the recommended distances between various elements of public transport system for a commuter access.

Public Transport Matrix

Road Type	Bus stops @	Bus Bays @	Transit Hubs @	Feeder Bus stop @	Bus Rapid Transit @	Mass Rapid Transit @	Trip planners @	Route Maps @
Arterial	500 m	2 km	4.7 sq km		1 - 1.5 km	2 km		
Sub Arterial	500 m			500 m	1 - 1.5 km	3 km	Every Bus stop	Every Bus stop
Collector	400 m			300 - 400 m				
Local				300 - 400 m				

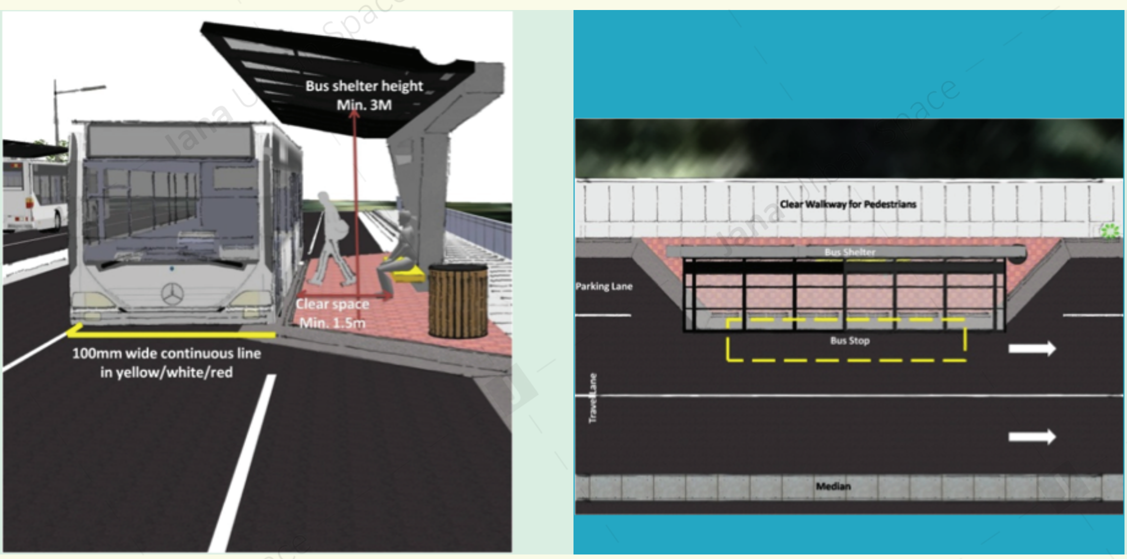


Image 2.7 >>
Plan and view showing extended kerb for Hail-n-Ride Bus Stop

Bus stop locations & clearance lengths:

Nearside: just before an intersection –clearance of 35 m
Farside: just after an intersection - clearance of 42 m
Mid block: between two intersections - clearance of 25 m

Bus stops close to the intersection can lead to traffic queues and sight distance issues, but are more desirable from the commuter point of view for the ease of transfers. Mid-block stops may be better near a congested intersection, but may lead to frequent mid-block pedestrian crossing incidents. The advantages and disadvantages of these choices must be analysed based on the ground conditions in consultation with the transit authorities.

2.2.3 >> Bus Bays

A **hail-&-ride bus stop** blocks the ongoing traffic resulting in congestion, especially on narrow roads during peak hours. To achieve free flow of traffic on main travel lane, a bay is provided outside the main travel lane for buses to stop for the passengers. This reduces traffic blocks and increases passenger safety.

Transport Hubs

A transport hub is a place where route or mode interchange is made available for passengers. Public transport hubs include train stations, rapid transit stations, bus stops, tram stop and airports. In most Indian cities, a hub is the merging place of inter-city buses; intra-city buses; intra-state transport service; parking lot for private vehicles; and control rooms. It is decentralized forms of bus stations which is planned and all major mergers of corridors of a city.

A transit hub attracts other intermediate public transit (IPT) like auto, taxi, feeder and other para-transit vehicles. Sufficient space should be allocated near these hubs to accommodate all IPT. All hubs must have dedicated entry and exit. Parking restrictions must be enforced on all roads that lead to the hub.

2.3 >> R-o-W & On-street Parking

With more and bigger cars on urban roads everyday, the impact is not just on traffic movement, but on street congestion that hampers pedestrian movement and access to dwellings. The issue of parking is reaching alarming proportions. There are four causes for this:

1. ***P***arking is either free or at a nominal cost.
2. ***V***iolations in parking rules such as double-parking, hap-hazard parking, and parking in no-parking areas, go unpunished. This leads to a culture of violating traffic laws. Violations in space parking requirements in buildings also go unchecked and unpunished
3. ***B***ig retail and commercial developments either do not provide adequate parking for their customers, and/ or the roads providing access in and around the development do not have the carrying capacity for the traffic they generate.
4. ***P***oor planning that does not link land use to trip generation and parking requirements. Parking policies for buildings and streets need to be simplified so that there is no scope for negotiation, and such that they are easy to monitor.

Considerations for provision of parking type:

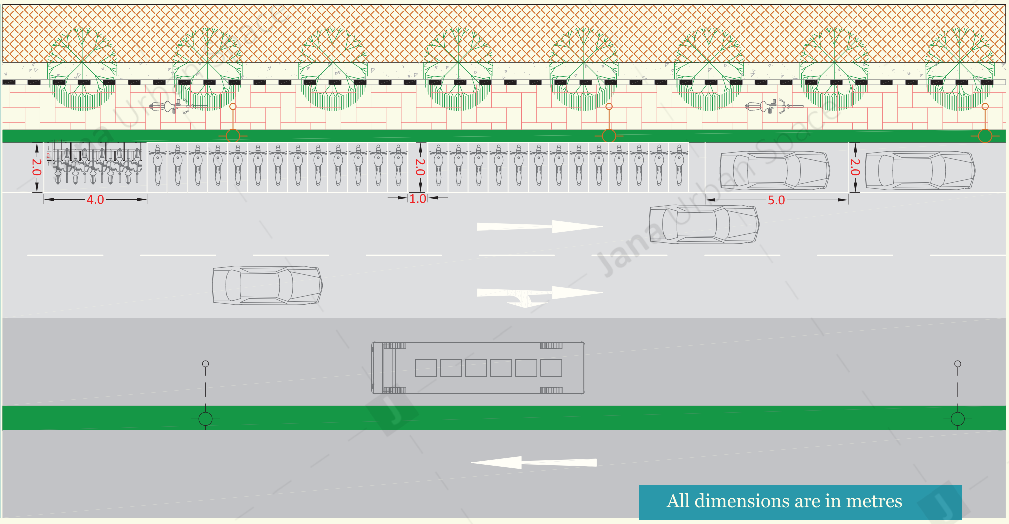
1. ***F**ree public parking: residents obtain permits, and visitors have off-peak parking*
2. ***P**aid public parking: in designated areas and streets, around transit stops and high traffic destinations*
3. ***P**aid private parking: through PPPs using hi-tech for multilevel parking, in CBD areas and key high traffic centres, around major rail stops, and where pedestrian use is desirable.*

Mini routes with mini public transport modes can be chalked around key public transit and pedestrian areas, which also include a parking location where commuters can park their vehicles.

This section is limited to specifications for on-street parking, and does not go into any details on policy recommendations

Parking lane width for parallel parking should be 2.75 m x 6 m which may be reduced to 2 m x 5 m where available space is limited. Where additional parking capacity is desired and sufficient carriageway width is available, angled parking may be adopted. Standard dimensions required for different angles of parking is as indicated overleaf:

Plan 2.8 >>
Parking of 4-wh, 2-wh and bicycles



Parking policies for buildings and streets need to be simplified so that there is no scope for negotiation, and such that they are easy to monitor.

For every 1000 sqm of built up residential space approved, parking of 10 cars, and every fraction thereof, can be the minimum standard
For every 1000 sqm of built up commercial space approved, parking of 20 cars, and every fraction thereof, can be the minimum standard

Table 2.4 >> Parking Space requirements

Sl. No	Type of Parking	Standard space (m) (w x l)	Reduced space (m) (w x l)	Notes
1	Parallel	2.75x6	2.5x5	Parallel parking requires experience, best in local roads
2 4	90°	2.75x6	2x5	Effective in low turnover rate or long term parking areas, the perpendicular, or 90 degree parking configuration is the most efficient and economical since it accommodates the most vehicles per linear meter. Public parking lots.
3	60°	2.75x6	2.5x5	Ideal for a fast turnover rate or predominantly short term use Often offset by difficulties of inefficient circulation patterns and one-way aisles. Collector, Sub-arterial
	30°	2.75x6	2.5x5	

This includes all parking: private, paid, and public.
The recommended minimum space standard for cars with standard dimensions, in private buildings, including circulation is as follows:
20 sqm surface parking
23 sqm parking under stilts
28 sqm parking in basements

1 car parking space = 4 two-wheeler space = 10 cycle space
A typical two-wheeler parking space is 1.2 m x 2.5 m. In places with space constraints this can be reduced to 1 m x 2 m.

While deciding the specific locations for on-street parking and the number of parking spaces should be provided, due consideration should be given to loss in road capacity in permitting parking. Parking area should be designated after providing space for pedestrians, green strip and cyclists. Parking should not be allowed 100 m into intersections to reduce conflicts and to give additional travel lane width for vehicular movements. Provision of footpaths should be an uncompromised priority, with suitable safeguards against illegal parking on them. The table overleaf gives the type of parking recommended for urban roads.

Image 2.9>>
On-street parking on a residential street in Europe

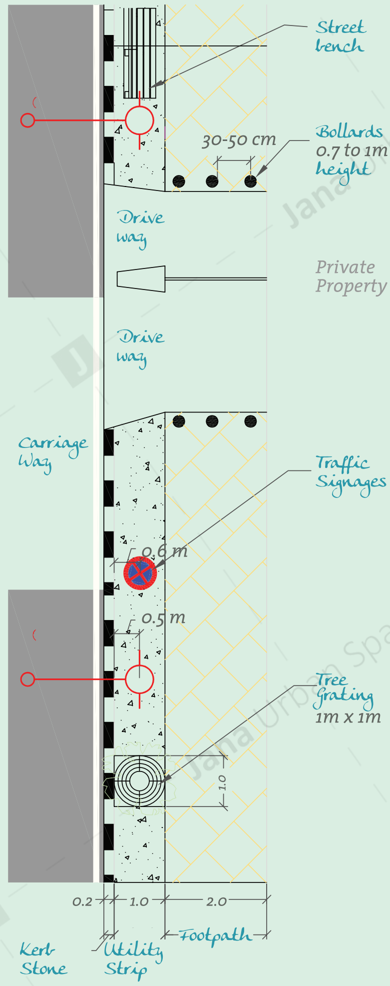
Urban Road Type	Angle	4 wh	2 wh	4 wheeler parking on commercial areas				2 wh
		Feeder Road		1 side	2 side	off street	metered	
Arterial (48m)	Parallel	■			■		■	
	30							
	45							
	60							
	90		■					■
Sub Arterial (30m)	Parallel				■		■	
	30	■		■				
	45					■	■	
	60							
	90		■					■
Collector (21m)	Parallel							
	30			■			■	
	45							
	60							
	90		■					■
Local (10m)	Parallel			■		■		
	30							
	45							
	60							
	90							■
Sub Local (3m)	Parallel		■					■
	30							
	45							
	60							
	90							

Table 2.5 >>
Road Types
& Parking

2.4 >> R-o-W and Pedestrian Area

Non-Motorized Transport (NMT) must be given greater weightage while designing urban mobility. **Mobility** is allowing people to move from one place to another, safely and conveniently, considering socio-economic conditions, characteristics of the area and accessibility to other modes. Therefore it is important to develop a comprehensive mobility plan that accommodates motorized and non-motorized transport (NMT). Slow moving non-motorized transport modes, like bullock-carts, cycle rickshaws and hand-drawn carts are not touched upon in Tender SURE.

Image 2.10>>
Need for safe
pedestrian crossing
Bangalore city



Plan 2.11>>
Plan view of footpath showing street fixtures, landscaping and building driveway

2.4.1 >> Footpaths

The space by the side of the road identified for pedestrian walking purposes is usually referred as 'pedestrian pavement/ walkway/ footpath. **Pedestrian** area includes space for footpath, landscaping, street furniture, signage, and above-grade utilities. This area may also be shared by bicycle users. The pedestrian area is closely linked with the travel lanes and on-street parking. The width of the 'pedestrian pavement' can vary based on the number of pedestrians using the road. From uneven granite slabs to interlocking pavers of various shapes (circular, hexagonal, eye-sections, colored and grey) and just simple rough concrete slabs, there are many choices and designs that have evolved in the last twenty years.

Recommended minimum width for pedestrian walkway/footpath and bicycle track is 1.5 m. They should have well maintained surface with a cross fall within the range of 2.5 to 3 %. Except sub-local 2m and 3m R-o-W *(Refer drawing plate 19, page 158)*, footpath is provided on either side of the road in all scenarios.

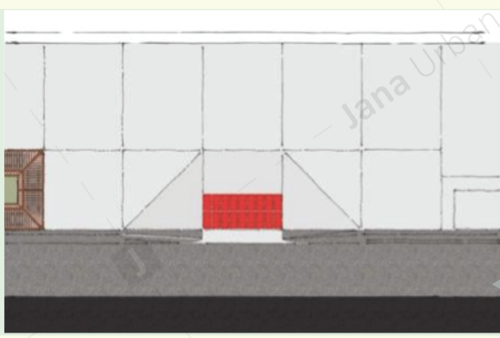
Minimum footpath width is maintained at 1.5m and maximum is 3m. Where additional width in the RoW is available, this can serve as landscaping or foot path extensions for small markets or hawking areas.

2.4.2 >> Kerb

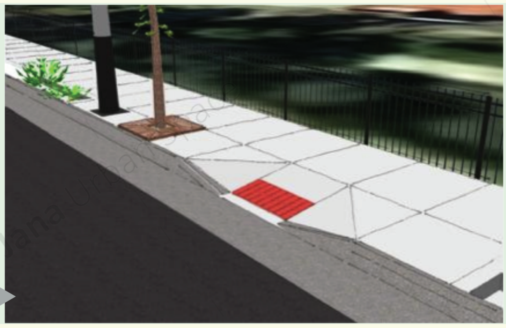
Kerb is a key element that divides travel lanes and pedestrian walkway. The main purpose of kerb stone is to protect and strengthen pavement edge, to control drainage, clearly defining the edge to vehicle operators. It may be made of plain cement concrete. Height of a kerb usually varies from 15 cm to 25 cm. There are various types of kerb designs that accommodate various needs such as 'L' type kerb which includes a gutter. Kerbs are painted with either alternating black and white stripes 500 mm wide or chequered black and white design of same width.

Kerbs need to be dropped to facilitate mobility of persons with physical challenge. Footpaths are ramped to the street level along with the kerb ramps. Kerb ramp should be flared on either side of the ramped footpath and gradient of the flared side should not be steeper than 1:10. The ramp should not project onto a roadway.

Alternatively raised pedestrian crossings may also be provided to facilitate crossing.(*Refer subsection 2.6 Traffic Calming measures*).



Plan view 2.12 >>
Plan showing
Drop Kerb



Perspective
View 2.13 >>
Drop Kerb

2.4.3 >> Street furniture/ Landscaping strip

A dedicated space is provided adjacent to the kerb for landscape elements such as shrubs and flower plants, trees, street furniture such as, street bench, trash bins, and above-grade utility fixtures such as light poles and signage etc. This strip will not only act as divider between pedestrians and vehicles but it also improves aesthetical features of the road. Strip dimension varies based on the available footpath width and clear walkway designed for pedestrians. Minimum width given for landscaping strip is 0.4 m in local road and can be 1 m and more in higher order roads.

	Traffic signs	Street light	Tree/ plants	Dust bins
Distance from the Kerb (m)	0.6	0.5	0.7	0.2

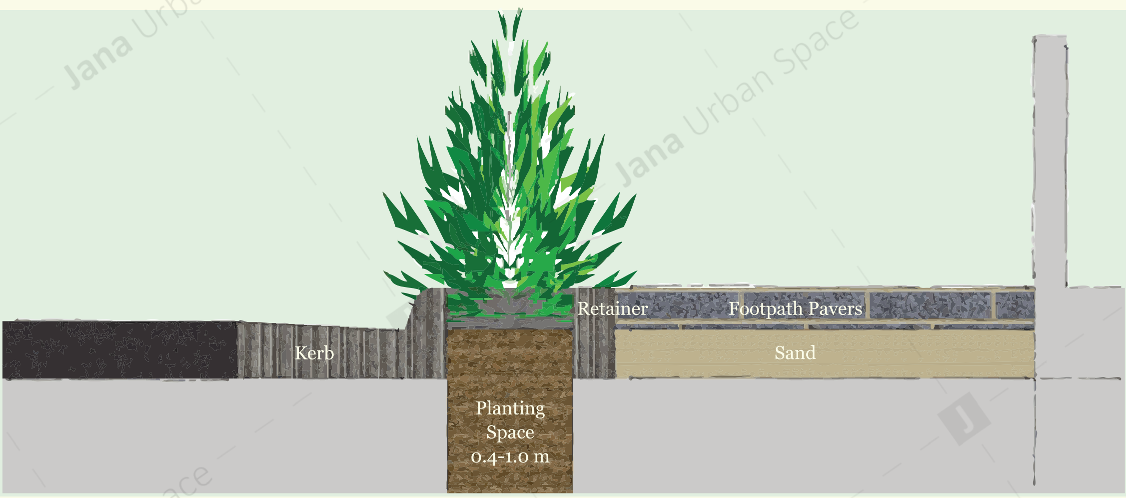


Image 2.14 >> Green strip on a Local Road (Walton Road), Bangalore

2.4.4 >> Bicycle Path

The **bicycle** is a core mode of urban transport. It is desirable to re-design R-o-Ws prioritising bike lanes in all arterial, sub-arterial and collector roads by

1. ***N***arrowing existing travel lanes
2. ***R***emoving a travel lane
3. ***R***emoving parking
4. ***C***overing drains and extending the footpath

For bicycle track a 1.5 m minimum width is maintained on collector roads and in sub-arterial and arterial road 2 m width is provided. Since speed of travel (refer Table 2.2) is less on local and some collector roads, a dedicated lane may not be needed.

Image 2.15 >>
Bicycle track in
Delhi (source: ITDP)

Features of Bicycle track

1. ***A*** minimum width of 1.5 m for one-way movement and 2.5 m for two-way movement continuity to allow for reasonable speeds
2. ***A*** smooth surface material—asphalt or concrete. Paver blocks are to be avoided. Manhole covers should be avoided and, if unavoidable, should be level with the surrounding surface
3. ***E***levation above the carriageway (e.g. +150 mm) that allows for storm water runoff
4. ***A*** buffer of 0.5 m between the bicycle track and parking areas or the travel lane is provided
5. ***A***t property access points, the bicycle track remains at the same level and vehicle access is provided by a ramp in the buffer
6. ***B***ollards to block access to motorbike users

As shown in Plan 2.16 a dedicated space may sometimes be provided for cyclists to halt ahead of private lanes at an intersection. Dedicated signals at intersection gives priority to cyclists after BRTS.

Plan 2.16 >>
Bicycle stopping
area at intersection

2.4.5 >> Pedestrian Crossing

Intersections are critical areas of pedestrian congregation and require safe and efficient crossing facilities while ensuring minimum delay to vehicular traffic. Skywalk bridges/foot-over-bridges forms a very important aspect for overall improvement of transport infrastructure in the city and helps pedestrians to improve their safety and mobility.

Design considerations for pedestrian underpasses, bridges and subways

The flow should not normally exceed 20 persons per 300 mm width per minute on level or up to 1:20 gradient and 14 persons per 300 mm width per minute on stairs or ramps steeper than 1:20. A dead width of 0.75 m is usually allowed adjoining any display windows in subway.

The gradients of continuous ramps should not be steeper than 1:10. If a landing is provided at mid – height, a maximum slope of 1:7 can perhaps be allowed. A minimum height of 2.3 m and a width of 2.45 m should be provided for subways up to about 23 m length, and for longer subways the dimensions need to be increased to 2.6 m height and width of 2.75 m.

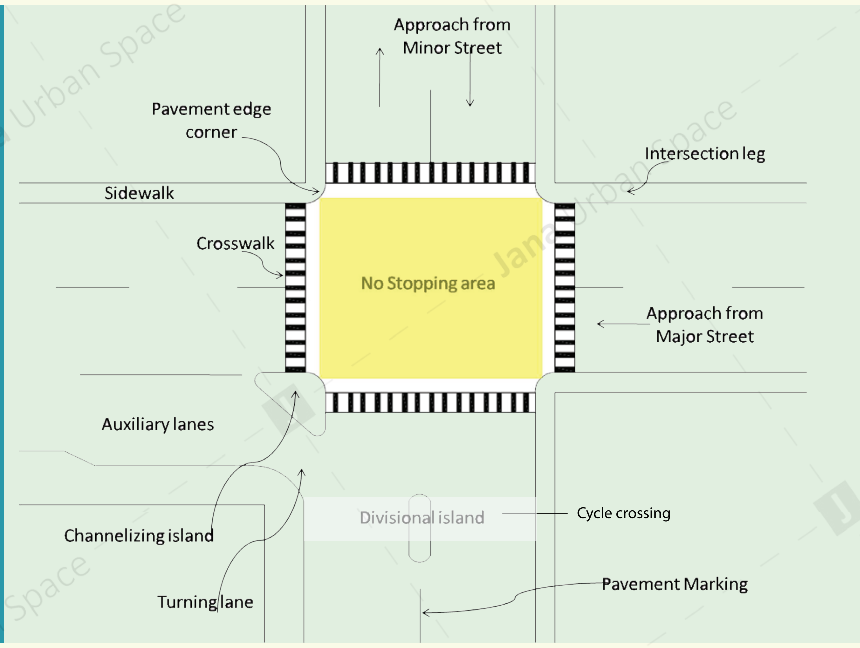
In order to overcome the drawbacks of pedestrian subway, the middle portion of the junction may be raised.

Image 2.17 >> Underpass below a screened major arterial road in Gstaad, Switzerland

2.5 >> Road Intersection

Intersection is a point at which two or more roads cross. This area is designated for movement to turn directions. Overall traffic flow depends on the performance of the intersections.

Intersection design needs to be based on factors such as : users, geometric configuration, volume of travel, capacity of roads and traffic control requirements.



Plan 2.18 >> Intersection components

2.5.1 >> Intersection Variables

1. ***N***umber of roads converging
The number of roads converging governs the configuration and shape of the intersection. Typically there are three or four legs in any intersection; however intersections with 5 or 6 legs are also formed where three roads converge.

2. ***R***-o-W widths of intersecting roads
In urban road hierarchy, traffic flows from sub-local to local or collector; local to collector; collector to sub-arterial and sub-arterial to arterial.

Intersection formed due to local + local and local + collector roads might not require treatment as neighborhood traffic would be low. But when two major R-o-Ws intersect, detailed designing is required.

3. ***I***ntersection design based on amount of traffic

Traffic management at intersections:
(i) Traffic < 3000 vehicles/hr - Calming measures

(ii) 3000 - 6000 vehicles/hr - Mini traffic circle or rotary
(iii) 6000 - 8000 vehicles/hr - Signalised intersection
(iv) 10,000 & above vehicles/hr - Grade separators

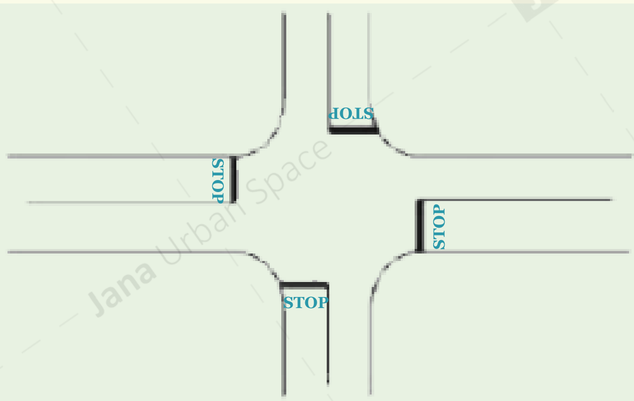
Table 2.6 indicates the type of intersection design to adopt based on the traffic generated.

Table 2.6 >> Recommended Intersection based on intersecting Road Types

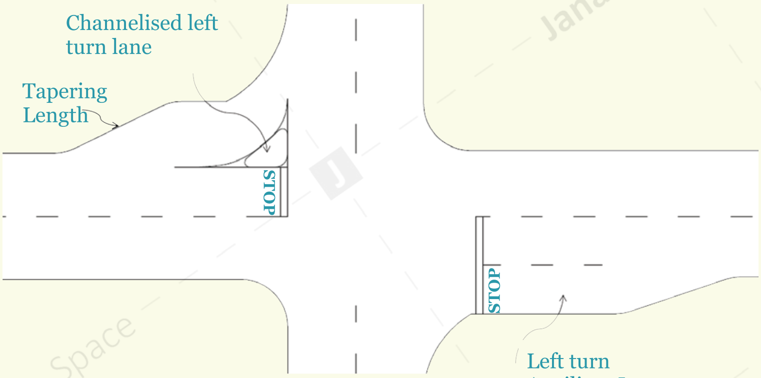
Intersection formed due to merging of	Mini Traffic Circle (slightly more than rotary)	Rotary with single circulatory lane (3000 veh per hr)	Rotary with Double circulatory lane (3000 veh per hr)	Signalised (upto 10000 veh per hr)	Grade Separator (Above 10000 veh per hr)
Arterial + Arterial					●
Arterial + Sub Arterial					●
Arterial + Collector Street				●	●
Sub Arterial + Sub Arterial				●	●
Sub Arterial + Collector				●	●
Collector + Collector		●	●	●	
Collector + Local		●	●		
Local Street + Local Street	●				

2.5.2 >> Types of intersection

2.5.2.1. *Simple intersections*
An intersection where the R-o-W widths of all converging legs are the same and additional space for turning traffic is needed or cannot be provided due to constraints of adjacent land use. This type of intersection is suitable for locations where two local road meets another or with a low volume collector road. Pedestrian crossing distance in this type of intersection is the lowest of all intersections.



2.5.2.2. *Intersections with additional turning lanes*
In certain locations with high-volume traffic, additional lanes need to be provided to accommodate turning traffic and to create additional capacity for through traffic. This is achieved by utilizing the space in the medians, utility corridors or by flaring. Crossing distance and time for pedestrians increase in this type. This needs to be factored in the design to create adequate pedestrian refuge areas and traffic controlling.



2.5.2.3. *Channelised* Intersections

Raised islands and/or road marking are used to 'channelise' or designate vehicular paths in the intersections. Channelisation helps in control, direction or division of vehicular paths for better traffic management of motorised and non-motorised vehicles. Locations for traffic control devices, utilities should also be factored in the design. The channel islands and median spaces should provide refuge areas for crossing pedestrians, since channelised intersections generally tend to be on wider R-o-Ws.

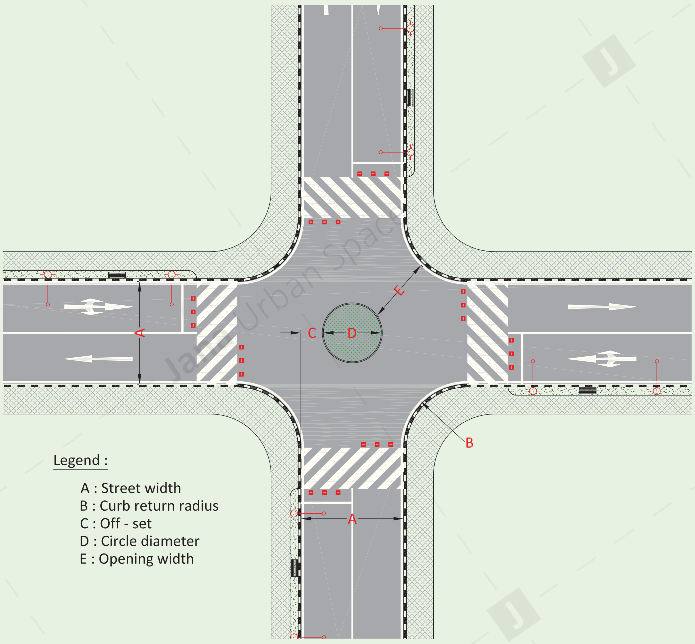
2.5.2.4. *Roundabout* intersections

Roundabouts channel movement of traffic in one direction around a central island. The vehicles from the converging roads move around the central island in clockwise direction in an orderly manner and weave out of the rotary movement into their desired direction. A roundabout may be for three-leg or four-leg or multi-leg intersection. The central island is generally circular in shape, but can also be oval or dumbbell shaped. A roundabout intersection has less conflict points than a traditional intersection and is also considered safer.

Image 2.19 >>
Bird's eye view
of a roundabout

Mini traffic circles are types of roundabouts characterized by a circle of small diameter and traversable islands (central island and splitter islands). Mini-circles offer most of the benefits of regular roundabouts with the added benefit of a smaller footprint. As with roundabouts, mini-circles are a type of intersection rather than merely a traffic calming measure, although they may produce some traffic calming effects. They are best suited to environments where speeds are already low and environmental constraints would preclude the use of a larger roundabout with a raised central island.

Plan 2.20 >>
Mini traffic circle



2.5.2.5. *Grade Separated Intersection*

Grade-separated intersections can be used in locations where high volume through traffic needs be given preferential treatment. The grade-separated intersections are required when two major roads meet—arterial with arterial or sub-arterial, where volumes are high. There are various types of interchange-designs such as ‘trumpet interchange’, ‘diamond interchange’, ‘cloverleaf interchange’ and ‘rotary interchange’. These are conventional interchanges that require large space which is scarcely available in any Indian cities and construction duration is longer. Much of the time is spent on preparing ground for RCC, casting and curing. As it requires more time, alternate routes for movement are required.

Dense city centers needed a technology that is quick, effective and causes minimal disruption to traffic. Urban local bodies in recent times have shown a preference for pre-cast elements with push-box technique, because these are simple, quick and economical. In pre-cast technology major part of the construction work is done outside the worksite. RCC pre-cast elements can be made well before the work begins at the worksite and then brought to the pre-prepared construction site and placed in to position. Push box technique, originally developed from pipe jacking technology. Jacked box tunneling is generally used in soft ground at shallow depths and for relatively short lengths of tunnel. Images to the right show use of pre cast elements to construct underpass.

Image 2.21 >>
Jacked Box Tunnelling
(imagesource: http://indianrailways.informe.com/forum)

Image 2.22 >>
Under Pass construction on Hosur Road, Bangalore using pre cast elements and soil nailing techniques

2.5.3 >> Treatments of intersections

(See drawing plates Pg 66-81)

Majority of accidents happen at intersection because of blind spots especially at free left turns. Speed control measures need to be adopted to cut the speed. In vicinity of residential neighborhoods, institutions, transit centers and hospitals, appropriate TCM should be provided. *(See drawing plates Pg 66-81)*

The treatment method adopted in Bangalore is one-way system and dividing the roads with a median. A study conducted by Vivian Robert and A.Veeraragavan, Department of Civil Engineering, Bangalore University, suggests that, the conversion of two-way roads into one-way roads has led to a significant reduction in the number of accidents. Fatal accidents have reduced by 32%, injury accidents have reduced by 34% and property damage accidents have reduced by 18 % on the roads selected for the study.

The erection of median barricades on certain roads in Bangalore city are believed to have led to a significant reduction in the number of accidents. Fatal accidents have reduced by 40%, injury accidents have reduced by 43% and property damage accidents have reduced by 43%

on the roads selected for the study.

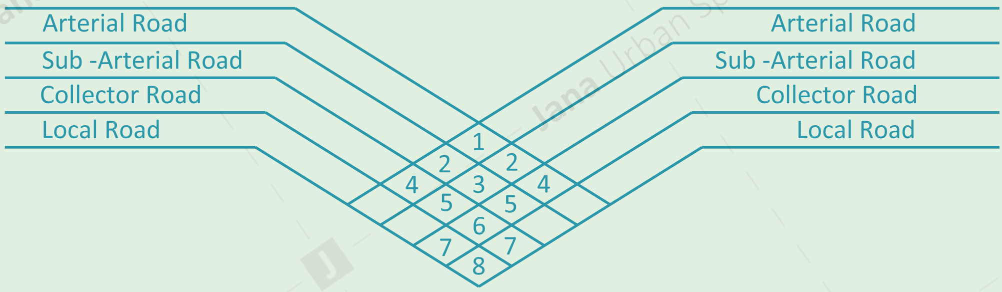


Image 2.23 >>
Intersections with varying road types
(See drawing plates Pg 66-81)

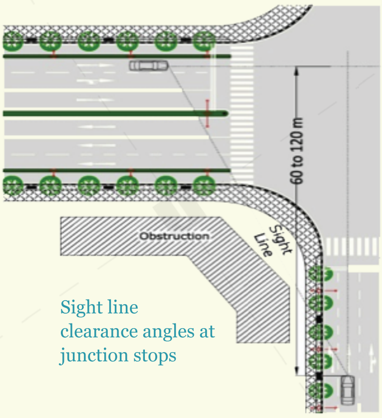
2.5.3.1 >> Sight distance at intersection

Sight distance is measured along the major roadway from the center of the entrance lane of the minor roadway to the center of the near approach lane (right or left) of the major roadway

The intersection sight distance is a major control for the safe operation of roadways. Sight distance at intersection plays very important role, mainly at uncontrolled intersection, so as to provide the driver to cross the intersection without causing delay or accident. The uncontrolled intersection sight distance requires that drivers approaching an uncontrolled intersection on a cross street must have sufficient sight distance across the intersection corners to adjust speeds or stop.

No distinction is made between daytime and night time conditions of vision at intersections, assuming that headlights of cars approaching the intersection will be seen across the corner area, and the headlight beams would usually indicate their presence before they actually come into view.

At signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches.



Sight line clearance angles at junction stops

Table 2.7 indicates visibility distances (meter) along major road of the intersection; the visibility distance is measured from the intersecting point of through sight of major road and minor road.

Table 2.7 >>
Safe stopping sight distance at urban intersections

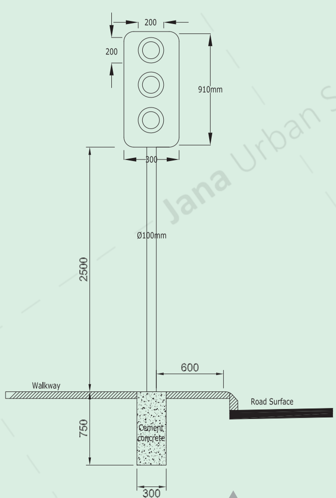
Safe Stopping Sight Distance At Intersection

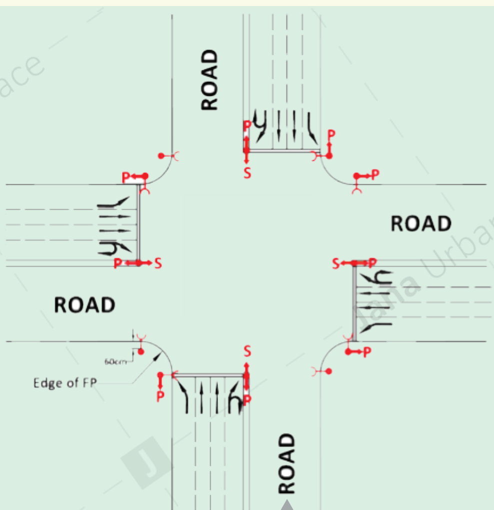
Speed (kmph)	SSSD (m)
20	20
25	25
30	30
40	45
50	60
60	80
70	90
80	100

2.5.3.2 >> Signalized Intersection

(See plates 10 & 11 - Pg 149 & 150)

A traffic signal is traffic control device operated manually, electrically or mechanically by which traffic is alternately directed to stop and proceed. The traffic signal passes on its information using a universal color code red, amber and green.





LEGEND :

P - Primary signal
S - Secondary signal

Notes :
1. Signal poles are located 60 cm from edge of footpaths
2. In case of streets where central median not provided secondary may be located on the right FP.
3. Distance between primary and secondary should be 12m min and 36m max.

Section 2.24 >>
Signal Pole details

Plan 2.25 >>
Signal location in intersection

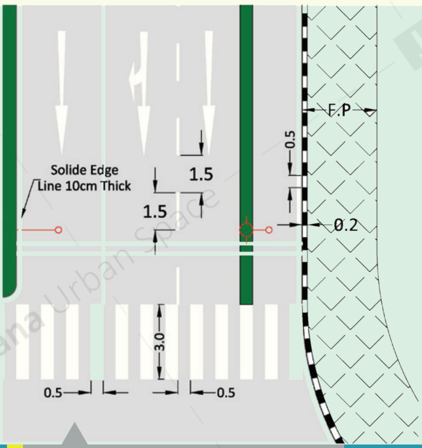
The signal sequence indication varies from country to country, in India practice we have amber period of 2 seconds as a transition interval between termination of related green movement and exhibition of red indication or vice versa.

Traffic signal is installed at two locations, one on the footpath towards left of approaching vehicles (termed as primary signal) and other on the opposite side of the road (termed as secondary signal). Signal poles are installed at a distance of 0.6 m from the kerb. In instances where a central median is not available, the secondary signal may be located on the right footpath.

The signal poles shall be installed in pits of 900 mm x 900 mm x 1050 mm deep embedded in M20 concrete to a minimum of 300 mm below ground level and 300 mm above ground level. The circular area of embedding concrete shall have a minimum diameter of 450 mm. All the cables supplying power to the controller and signal heads shall run through RCC ducts when these are required to cross the travel lanes. The ducts are of 150mm internal diameter and laid at a depth of about 750 mm from the level of the travel lanes.

2.5.4. >> Markings for intersection

In addition to the warning lines on approaches to intersections, directional arrows should be used to guide drives in advance approaching busy intersections. Because, of the low angle at which such markings are viewed, these are elongated in the direction of the traffic flow to provide adequate legibility. For speeds upto 50 kms per hour the arrows should be 3.5 m in length. For higher speeds, the length should be 5 m.



Plan 2.26 >>
Road Marking at Intersection

Image 2.27 >>
Box marking

2.5.4.1 >> Arrow markings, stop line, box marking and bicycle waiting area

Markings for cyclist crossing should be provided wherever a cycle track crosses a road. The cycle track crossing should ideally be adjacent to a pedestrian crossing when such a crossing is also provided. Rectangular box space is provided for bicyclists to wait during signals. The waiting area provided with a width of travel lane width and one bicycle length or 3 m breadth.

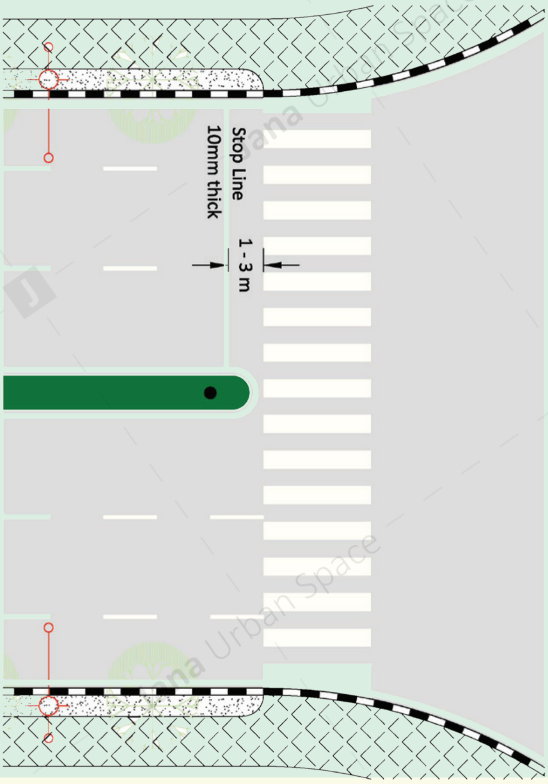
Image 2.28 >>
Bicycle waiting area marking

Image 2.29 >>
Cycle Crossing

2.5.4.2 >> Stop Line

Stop lines are solid white lines provided transversely to the carriage-way and used to indicate the point behind which vehicles are required to stop in compliance with the STOP sign, Traffic Signal or Traffic police. The width of stop line as per current Indian practice for urban and suburban roads are 20 cm.

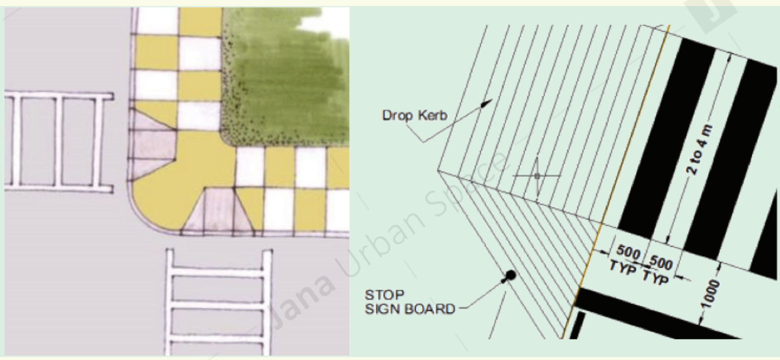
Stop lines are ordinarily located not less than 1 m and not more than 3 m in advance and parallel to the nearest boundary of pedestrian crossing marking.



Plan 2.30 >>
Stop line marking

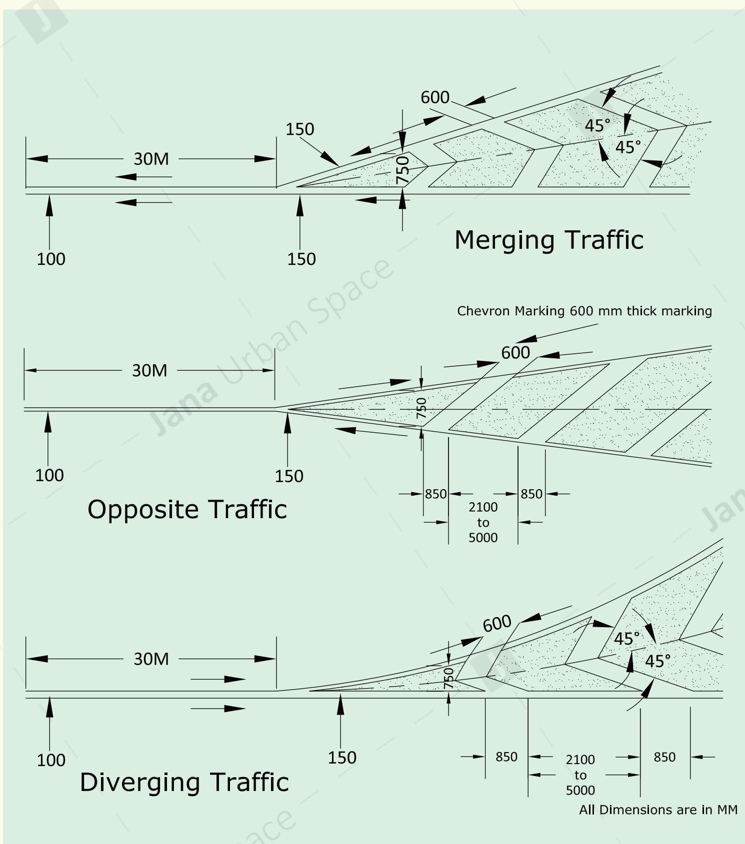
2.5.4.3 >> Pedestrian Crossing

Pedestrian crossings are marked at all intersections where there is substantial conflict between vehicle and pedestrian movements. The location of the pedestrian crossing should be selected properly to ensure adequate visibility, sufficient space on footway for the pedestrian to wait and freedom from obstructions. As per current IRC standard the minimum width of the pedestrian crossing should be 2 m and the maximum width should be 4 m and the marking bands should be 0.5 m in width and 0.5 m apart.



Plan 2.31>>
Drop Kerb
at intersection

2.5.4.4 >> Chevron Marking



Plan 2.32>>
Chevron marking

2.5.4.5 >> Box Marking

A **box junction** is a traffic control measure designed to prevent gridlock at busy road junctions. The surface of the junction is marked with a criss-cross grid of diagonal painted lines and vehicles may not enter the area so marked unless their exit from the junction is clear. Drivers MUST NOT enter the box until your exit road or lane is clear. However, one may enter the box and wait when you want to turn right, and are only stopped from doing so by oncoming traffic, or by other vehicles waiting to turn right.

2.6 >> Traffic calming measures

Traffic calming measures(TCM) on roads - such as changing alignment, introducing barriers, etc. - reduce traffic volume/speed. This improves the road safety and livability standards, especially to residential neighbourhoods.

Average reduction in traffic volume using TCMs are indicated in Table 2.8.

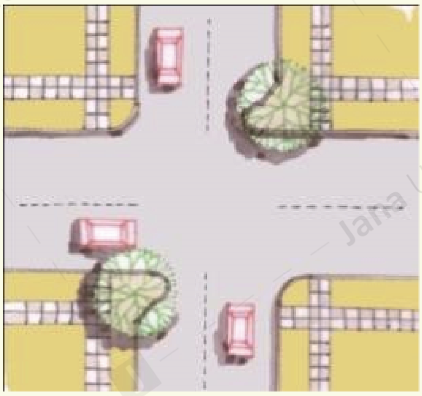
Table 2.8 >>
Traffic Volume Reduction due to adopting TCM (TCM, R. Ewings, Washington Institute of Transport. Published in APA Planners Press and American Society of Civil Engineers, 2009)

Sl. No.	TCM	Avg % reduction in traffic volume
1	Speed Humps	20
2	Speed Tables	25
3	Traffic Circles	30
4	Narrowings	45
5	Full Closures	60
6	Half Closures	80
7	Diagonal Diverters	90

Plan 2.33 >>
Full street closure

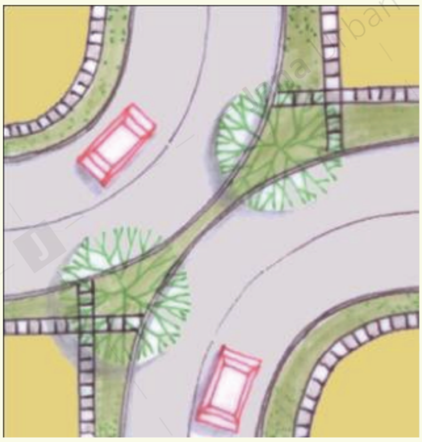
2.6.1. Full street closures

are barriers placed across a street to completed close the street to through-traffic, usually leaving only sidewalks open. They are good for locations with extreme traffic volume problems and several other measures have been unsuccessful.

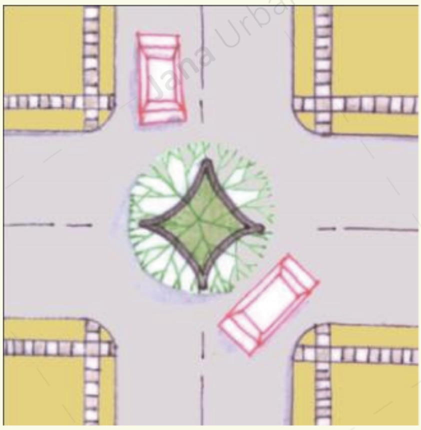


Plan 2.34 >>
Half closure

2.6.2 Half closures are barriers that block travel in one direction for a short distance on otherwise two-way streets. They are good for locations with extreme traffic volume problems and non-restrictive measures have been unsuccessful.



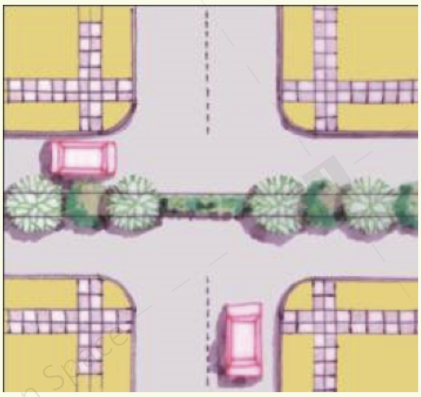
Plan 2.35 >>
Diagonal Diverter



Plan 2.36 >>
Star Diverter

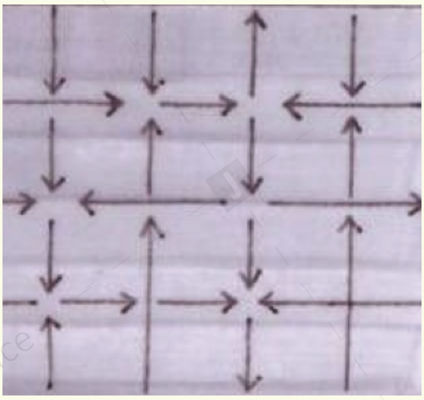
2.6.3.Diagonal diverters are barriers placed diagonally across an intersection, blocking through movements and creating two separate, L-shaped streets. Like half closures, diagonal diverters are often staggered to create circuitous routes through the neighborhood as a whole, discouraging non-local traffic while maintaining access for local residents. They are good for inner-neighborhood locations with non-local traffic volume problems.

Star diverter and truncated diagonal diverters are improvised forms of conventional diagonal diverters.



Plan 2.37 >>
Median Barriers

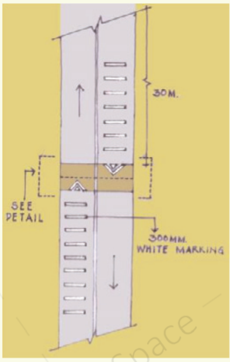
2.6.4. Median barriers are islands located along the centerline of a street and continuing through an intersection so as to block through movement at a cross street.



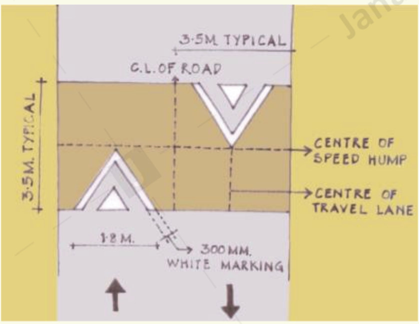
Plan 2.38 >>
One way system

2.6.5. One-way

When the volume on a particular stretch goes beyond the capacity of road creates congestion and frequent blockades for the traffic flow. In such cases, the traffic is allowed in one single direction.

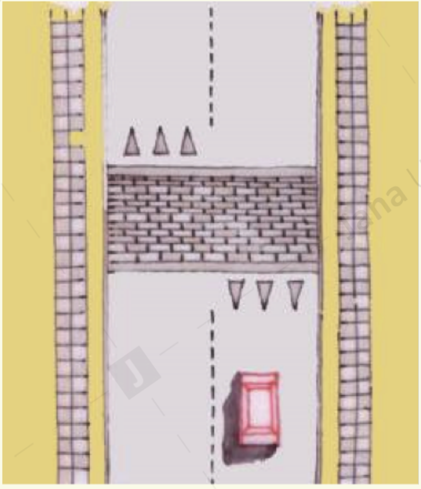


Plan 2.39 >>
Location & Marking Details of Speed Hump



Plan 2.40 >>
Details of Speed Hump

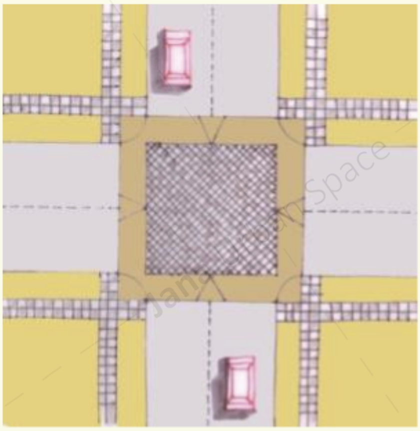
2.6.6. Speed humps are rounded raised areas placed across the carriageway. The profile of a speed-hump can be circular, parabolic, or sinusoidal. They are generally 3.5 m long and 12 to 15 cm high-speed humps are suggested 5 m ahead on a minor road meeting a major road.



Plan 2.41 >>
Plan of Speed Table

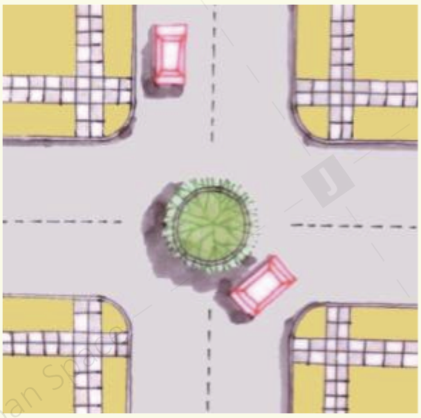
2.6.7. Speed tables are flat-topped speed humps often constructed with brick or other textured materials on the flat section. The profile of speed tables is trapezoidal. Generally, the top width of the speed table would be around 3 m and bottom width is 6 m. Speed tables are good for locations where low speeds are desired but a somewhat smooth ride is needed for larger vehicles.

2.6.8. Raised crosswalks are speed tables outfitted with crosswalk markings and signage to channelize pedestrian crossings, providing pedestrians with a level street crossing. Also, by raising the level of the crossing, pedestrians are more visible to approaching motorists. Raised crosswalks are good forlocations where pedestrian crossings occur at haphazard locations and vehicle speeds are excessive.



Plan 2.42 >>
Raised Intersection

2.6.9. Raised intersections are flat raised areas covering an entire intersection, with ramps on all approaches and often with brick or other textured materials on the flat section. They usually rise to the level of the sidewalk, or slightly below to provide a "lip" that is detectable by the visually impaired. By modifying the level of the intersection, the crosswalks are more readily perceived by motorists to be "pedestrian territory". Raised intersections are good for intersections with substantial pedestrian activity, and areas where other traffic calming measures would be unacceptable because they take away scarce parking spaces.



Plan 2.43 >>
Traffic Circle / Roundabouts

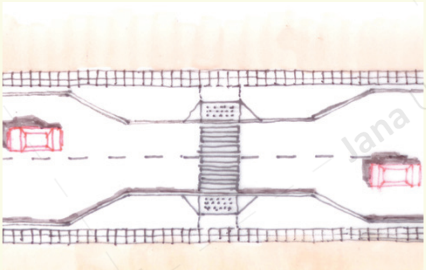
2.6.10. Traffic circles are raised islands, placed in intersections, around which traffic circulates. They are good for calming intersections, especially within neighborhoods, where large vehicle traffic is not a major concern but speeds, volumes, and safety are problems.

2.6.11. Roundabouts require traffic to circulate counterclockwise around a center island. Unlike traffic circles, roundabouts are used on higher volume streets to allocate right-of-way between competing movements.

Plan 2.44 >>
Chicanes

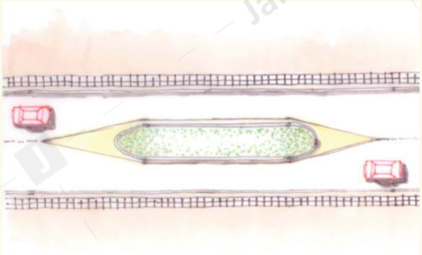
2.6.12.Chicanes are kerb extensions that alternate from one side of the street to the other, forming S-shaped curves. Chicanes can also be created by alternating on-street parking, either diagonal or parallel, between one side of the street and the other. Each parking bay can be created either by restriping the roadway or by installing raised, landscaping islands at the ends of each parking bay.

Good for locations where speeds are a problem but noise associated with speed humps and related measures would be unacceptable.



Plan 2.45 >>
Neckdowns

2.6.13. Neckdowns are kerb extensions at intersections that reduce the roadway width from kerb to kerb. They "pedestrianize" intersections by shortening crossing distances for pedestrians and drawing attention to pedestrians via raised peninsulas. They also tighten the kerb radii at the corners, reducing the speeds of turning vehicles. They are good for intersections with substantial pedestrian activity and areas where vertical traffic calming measures would be unacceptable because of noise considerations.



Plan 2.46 >>
Centre Island Narrowing

2.6.14. A center island narrowing (midblock median) is a raised island located along the centerline of a street that narrow the travel lanes at that location. Center island narrowings are often landscaped to provide a visual amenity. Placed at the entrance to a neighborhood, and often combined with textured pavement, they are often called "gateway islands." Fitted with a gap to allow pedestrians to walks through at a crosswalk, they are often called "pedestrian refuges."

Center Island Narrowing is good for entrances to residential areas, and wide streets where pedestrians need to cross.

2.6.15. Forced Turns : Forced Turn Islands are raised islands that block certain movements on approaches to an intersection. They are good for local street connections to main streets where through traffic volume along the continuing local street is a problem, and main streets where left-turns or through movements out of the side street are unsafe. (*Image overleaf*)

Plan 2.47 >>
Forced Turns

Table 2.9 emphasizes on various traffic calming measures that should be adopted in hierarchy of urban roads.

Table 2.9 >>
Pedestrian/
Traffic Calming
Elements

Road Element		Arterial	Sub Arterial	Collector	Local	Sub Local
		Road Type				
Priority		Movement		Mixed Usage	Safety, Access	
Footpath		●●	●●	●	●	Shared Path
Bicycle Path		●●	●●	●	Shared Path	
Public Transport*		●	●	●		
Parking	Bicycle		Minimal	●	●	Minimal
	2 wheelers		Should be avoided	●	●	Prohibited
	4 wheelers		Should be avoided	●	●	
Traffic Calming Measure				●	●	

● footpath and bicycle paths need to be adequately separated from the main travel area for safety

** Raised intersection is a physical traffic calming measure in which intersection is raised about 150mm from the road level that effectively cuts the speed there by allowing pedestrian to cross safely in intersections*

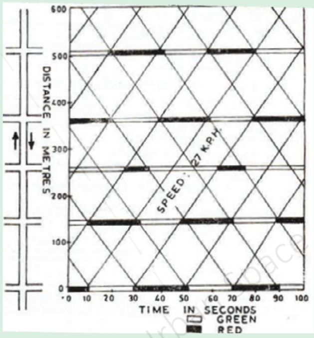


Image 2.48 >>
Typical time and distance diagram for one way street as with linked signals

Signal Synchronisation

Traffic Control Signals within 1km of one another along major route or in a network of intersecting major routes should be operated in coordination, preferably with inter-connected controllers. However, co-ordination need not be maintained across boundaries between signal systems which operate on different time cycles.

When a signal indicates a stop aspect at a junction, a queue of vehicles is formed behind the stop line. When the signal changes to green, the vehicle starts moving in the platoon. If this platoon is made to meet a green aspect at the next junction, no delay is caused to the vehicles. This principle of linking adjacent signals so as to a secure maximum benefits to the flow of the traffic is called coordinated control of signal. In general, the coordinating of signals is aimed at giving a progressive movement to traffic in a specified direction at a predetermined speed. In practice, it is usually found that about 60 percent of the vehicles are able to clear the intersection in the corridor.

Speed (kmph)		Distance (m)									
		100	200	300	400	500	600	700	800	900	1000
20	Time (in seconds)	18	36	54	42	90	108	126	144	162	180
25		14	29	43	58	72	86	101	115	130	144
30		12	24	36	48	60	72	84	96	108	120
35		10	21	31	41	52	62	72	82	93	103
40		9	18	27	36	45	54	63	72	81	90

Table 2.10 >>
Details of Time, Speed and Distance

2.7 >> Key recommendations for Universal Access on Urban Roads

Universal access for differently-abled citizens - including old people and children - is a critical feature of the road network. Texture, sounds, ramps and special allocations parking are elements that promote universal access. **Tactile paving** is a system of textured surface on footpaths, stairs and train station platforms that assist the visually challenged. The diagram below shows the tactile paver set into the footpaths.

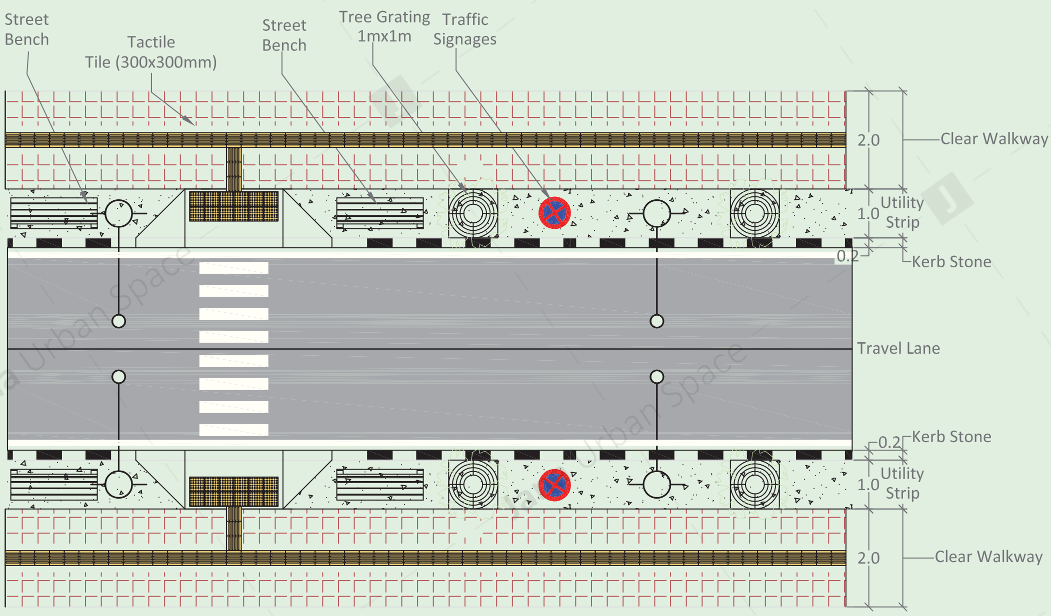
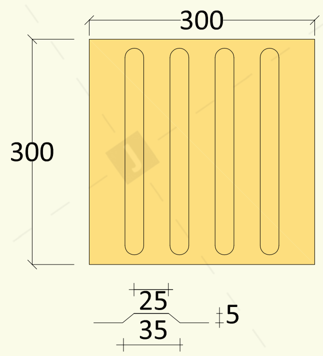


Image 2.49 >>
Tactile pavers on an urban road footpath

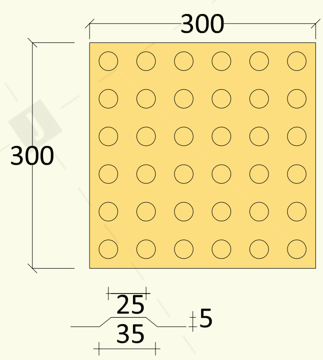
Key features of tactile pavers

1. **5** mm raised strips (as shown in the image overleaf) within the tactile tile.



2. *T*iles to have a contrasting colour (preferably canary yellow)

3. *W*arning (dot/blistered block refer fig below) strip around obstacles, drop-offs, corners, junctions or other hazards at 300mm distance around the hazard.



4. *T*he tactile paving used at pedestrian crossings is blistered (warning tiles). It should be laid across the entire footpath at a crossing and be 600 mm wide.

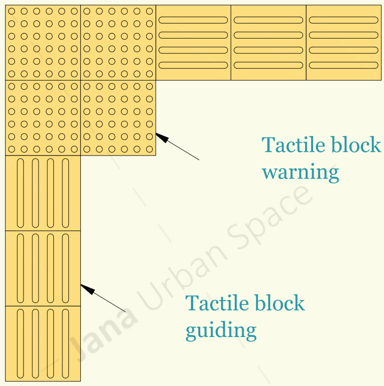


Image 2.50 >>
Layout of warning tiles

5. ***A*** distance of 600 mm (refer to image 2.51) to be maintained from the edge of footpath/boundary wall/any obstruction.

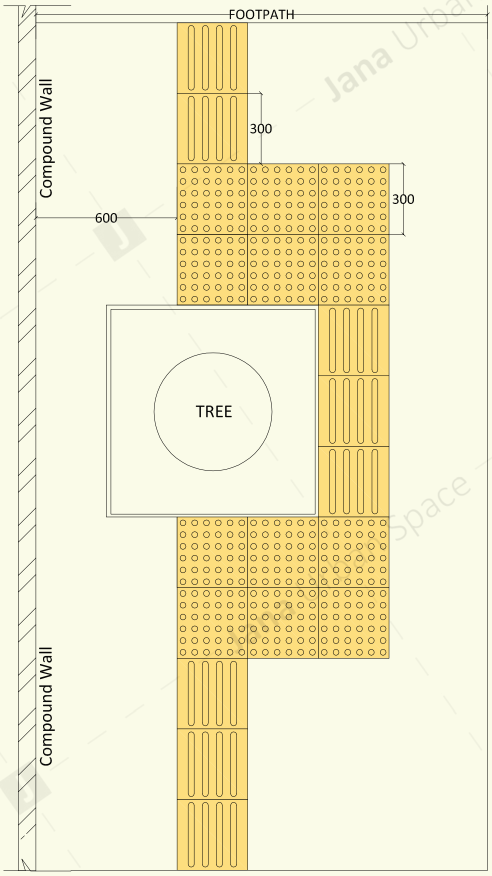


Image 2.51 >>
Guiding visually challenged pedestrians around obstructions

2.7.1 >> Recommended specifications for universal access at road intersections and pedestrian crossings

1. ***Key specifications***

a. ***A***t grade crossings must be provided in pedestrian priority areas and streets, with wheelchair access.

b. ***R***aised crossings should be designed with a minimum width of 2.4 m (as other crossings) and built at the same level as the footway.

c. ***G***rade separated crossings should be provided on high speed roads (>30km/h).

c. ***I***f grade separators provided at a high pedestrian and NMT priority zone (e.g. near to Metro or BRT stations,) the pedestrians and NMT must be kept at grade.

d. ***M***id block crossing must be provided at regular intervals as per the following standards: pedestrian crossing must be provided at all T junctions.

e. ***P***edestrian crossings with wheelchair access must be marked clearly and in detail (at grade/FOB, etc) and should have auditory signals.

f. ***A***t grade crossings with wheelchair access must be provided in pedestrian priority areas and streets.

g. ***G***rade separated crossings should be provided on high speeds roads (above 30km/h)
h. ***P***rovide appropriate crossings with dished kerbs marked with tactile paving.
i. ***K***erb ramp to be 1200mm wide, minimum 900mm, with maximum gradient of 1:20.
j. ***M***aximum height of the edge of a kerb ramp to be 20 mm.
k. ***P***revent vehicles from blocking sightlines at crossing.
l. ***A***void underground services access covers at crossings.
m. ***P***edestrian refuges for the disabled and elderly pedestrians on all roads with four lanes or more.
n. ***T***raffic islands and medians should be able to accommodate the length of a pram or wheelchair and pusher. The recommended width is 2 m.
o. ***A***t staggered pelican crossings including those without guardrails, two courses of tactile paving to link the two kerb edges to be provided while the rest of the central reserve should be paved normally.
p. ***P***edestrian crossing dimensions for universal access is listed in the table below;

Table 2.11 >>
Pedestrian crossing design for universal access

Ramp slope	8% maximum
Gutter slope	5% maximum
Flare slope	10% maximum
Lip at roadway	6mm maximum, flush surface
Ramp width	1200mm minimum, width of crossing
Landing width	1500mm
Cross fall on landing and approach	2% maximum
Width of tactile warning surface	610mm

2. ***Table Tops and crossing features for universal access***
Table Top – road raised to footpath/walkway level at crossing or with leveled or kerb rampto follow below :
a. 50 – 100 mm in height (no higher than 75 mm on a bus route)
b. ***S***pacing between 70-100 m
c. ***T***ypically 4-10 m long (on a bus route, the flat of a speed table should be at least 7 m long, so that the full wheelbase of a bus is on the top at one time).
d. ***R***amp gradients 1 in 12 to 1 in 20.
e. ***S***uitable for roads used by low floor buses.

Image 2.52 >>
Pelican signal
(Source: MikeonTraffic.com)

3. *M*id block crossings to be provided at regular intervals

Residential Areas:

Spacing Range: Every 80-250 m

Coordinated with entry points of complexes:

Location of bus/train stops, public facilities, etc.

Commercial / mixed use areas

Spacing range: Every 80-150 m

4. *Crossing* design

The recommended minimum width of a street crossing is 1200 mm. Central islands may be used to convert 2way roads into two separate one-way roads, which are easier to cross. Islands can also calm traffic and reduce vehicle speeds. Centre islands should be at least 2 m wide across the direction of the road to cater for wheelchair users, with a cut through at the surface level of the crossing, at least 5 m wide along the length of the road.

The safety of a crossing can be significantly improved by extending the footway out across any parking lanes (see image 2.9). This has the triple purpose of reducing the width of roadway to be crossed, slowing vehicular traffic and improving the ability of pedestrians and drivers to see each other. Crossings should be laid out with ample space, especially at the top of the kerb ramp to allow easy passage for pedestrians who are not crossing the road.

It is important to use consistent, predictable standards. For instance, the traffic signal pole should always be on the left (or the right) of the crossing; and the push button at the same height (about 1000 mm above the ground).

5. *Traffic signal cycles*

a. The red phase should keep traffic stopped for minimum 12 seconds for a 7.5 m crossing to allow wheelchair users and aged pedestrians to cross.

b. Signals to be activated by the pedestrian using a push button box (Pelican signal) at mid-block crossings. The signals have a beep which sounds during the first part of the green phase to indicate when it is safe to cross the road. The push button box should be located consistently at crossings. The push button box should have Braille buttons and raised alphabets for different signals, for example ‘s’ for stop and ‘g’ for go and so on.

c. A large diameter (up to 50mm) raised button that can be activated by a closed fist will be usable by most people. Traffic signal poles and push buttons should also be colour contrasted.

d.At signalized intersections audible signals to be provided to aid visually challenged pedestrians and children.

6. *Parking for Accessibility*

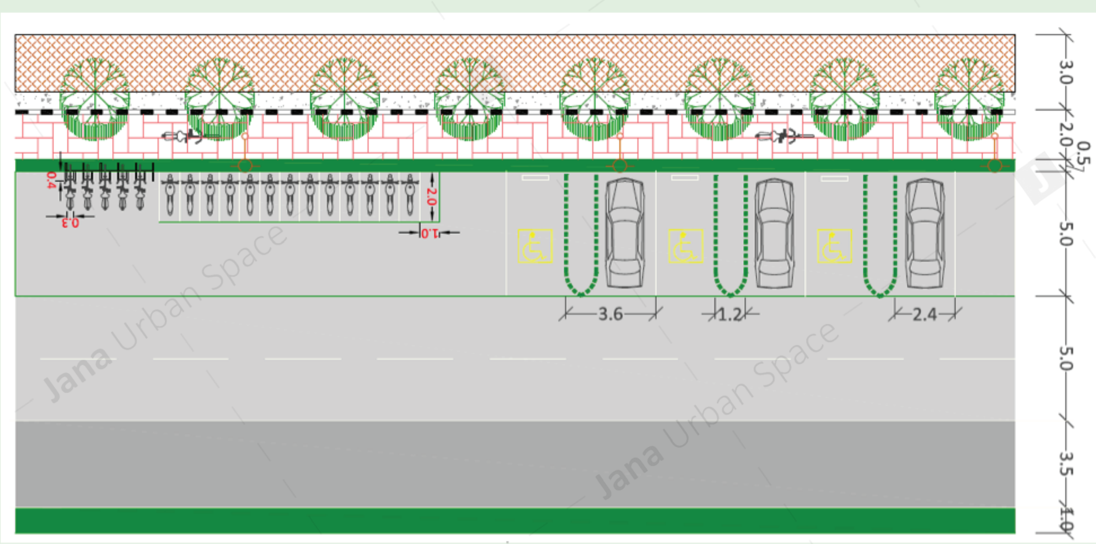
Where parking is provided, give special allocation tho persons with impaired mobility, so they may park their cars as convenient to entrances as possible.

a. Two accessible parking lots with overall minimum dimension 3600 mm x 5000 mm, should be provided.

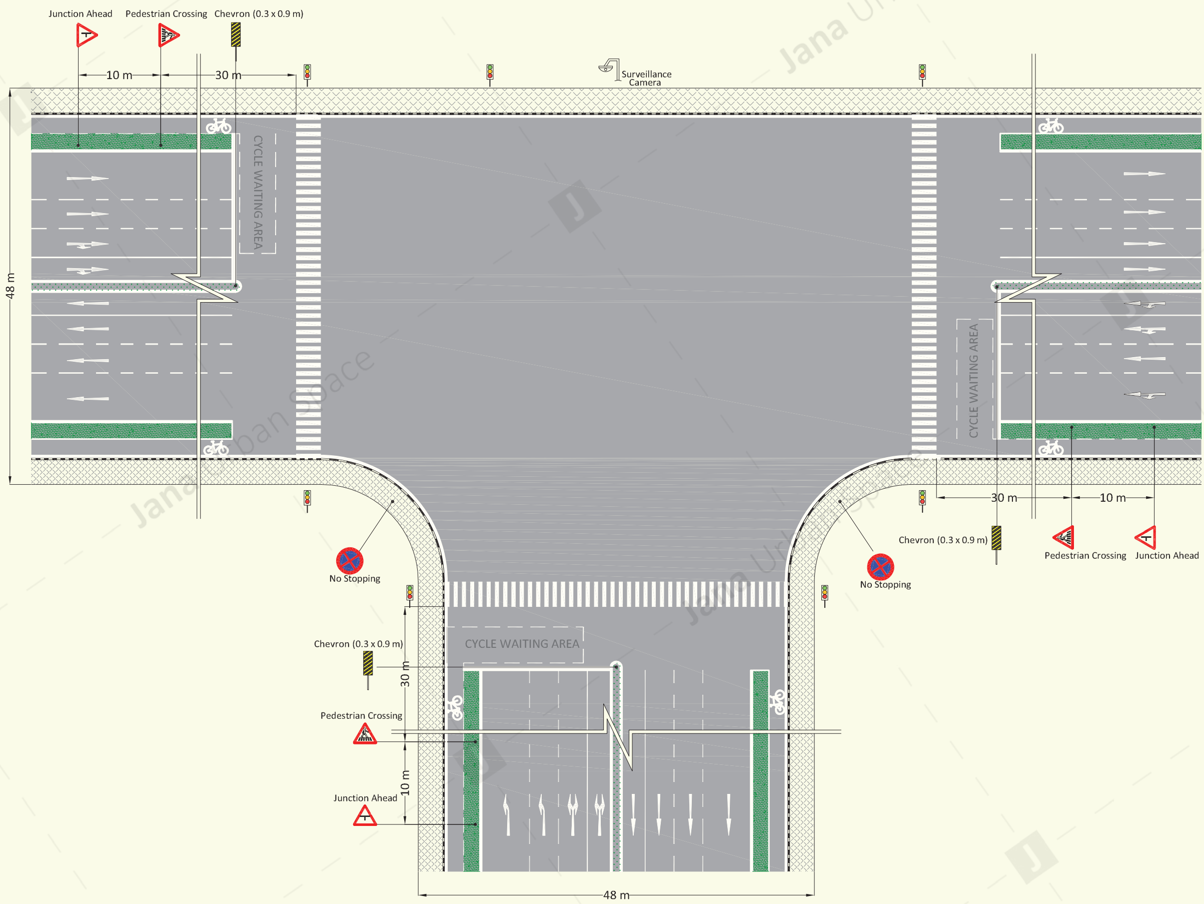
b. It should have the international signage painted on the ground and also on a signpost\board put near it.

c. There needs to be directional signs guiding people to the accessible parking.

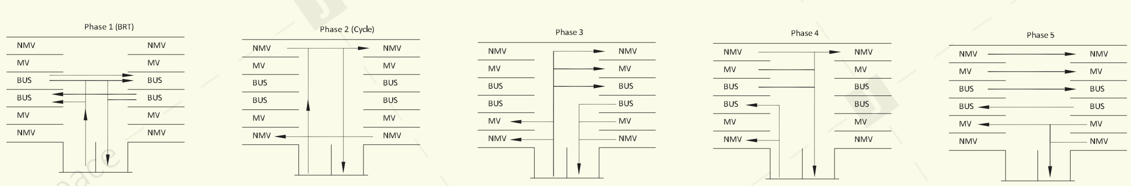
Image 2.53 >>
Accessible parking



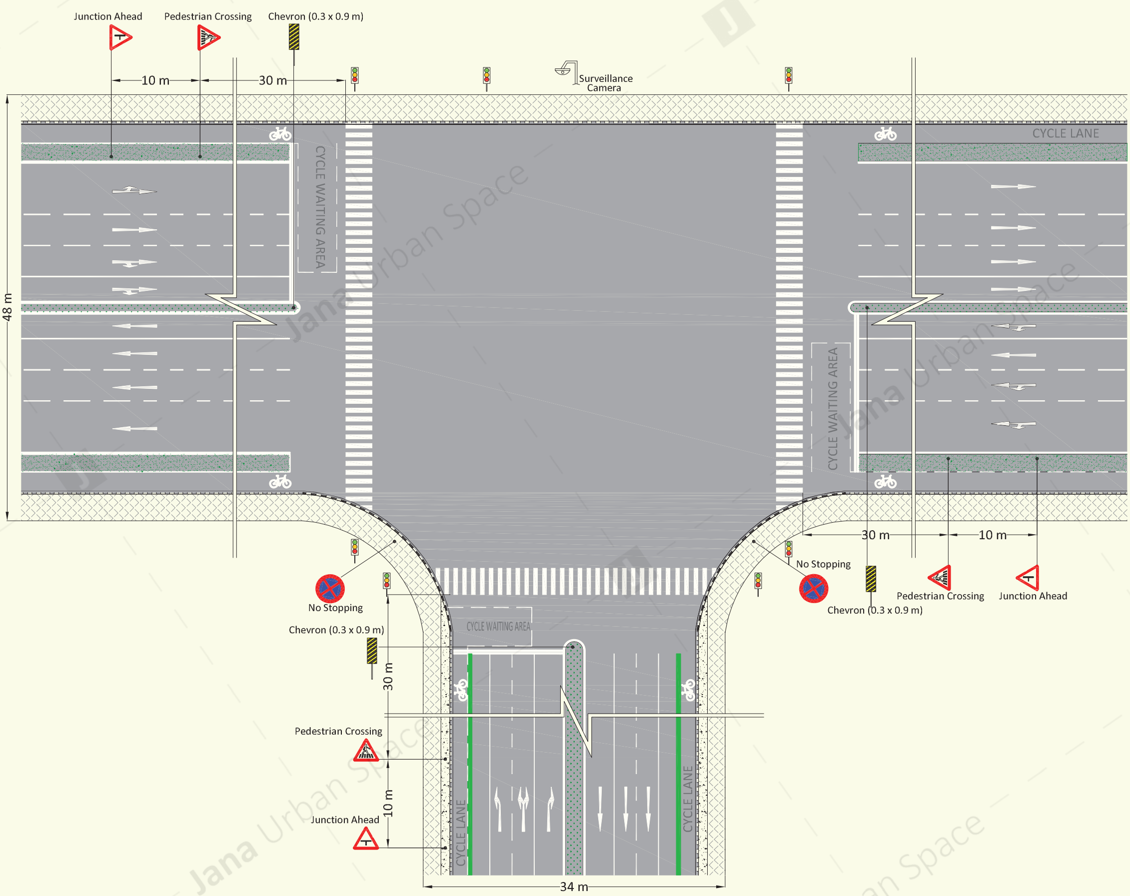
Arterial x Arterial - 3-leg intersection



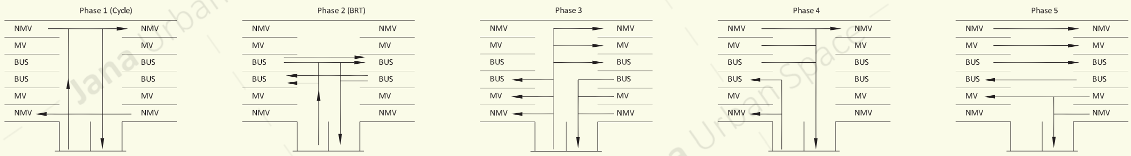
SIGNAL PHASE DIAGRAM



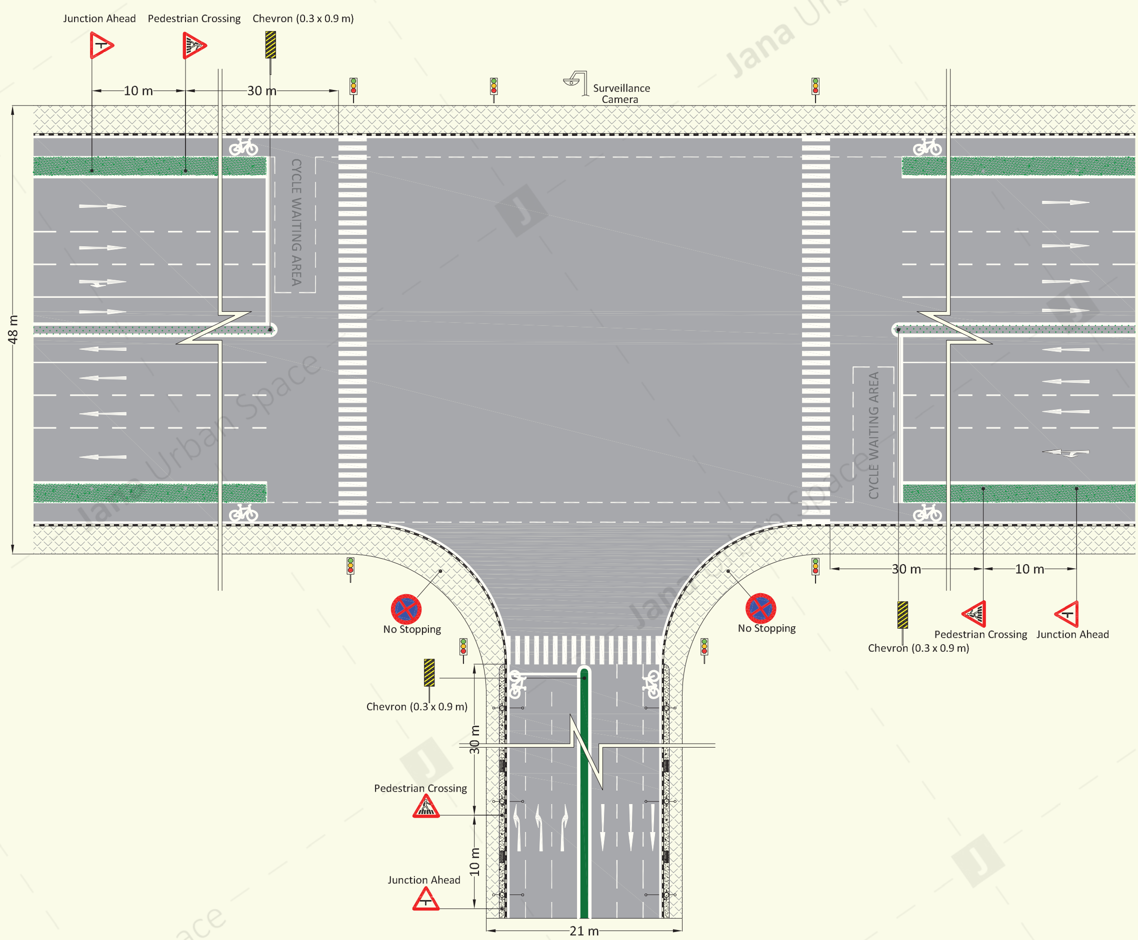
Sub-Arterial x Arterial - 3-leg intersection



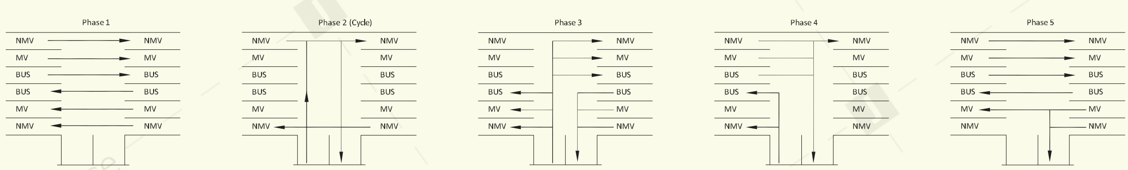
SIGNAL PHASE DIAGRAM



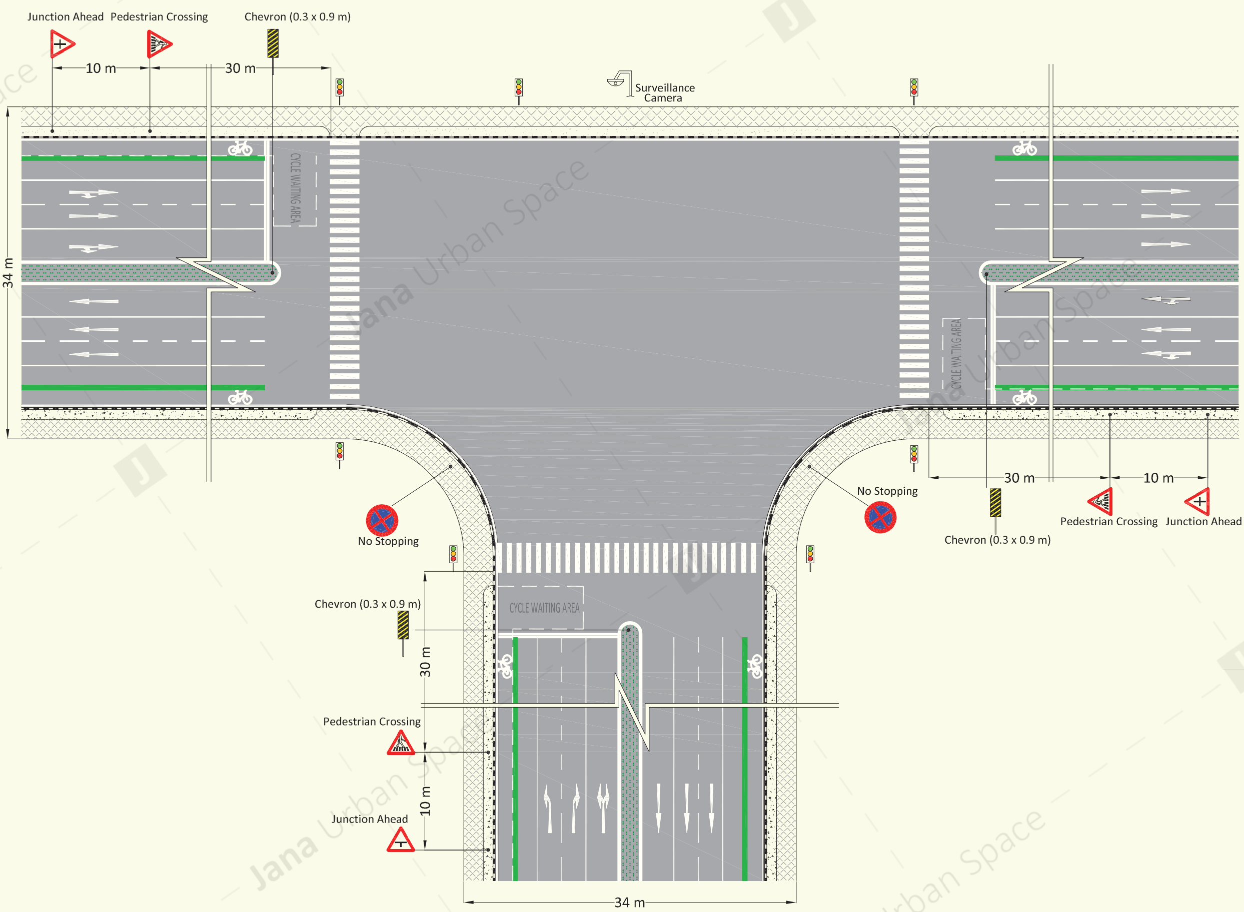
Collector x Arterial - 3-leg intersection



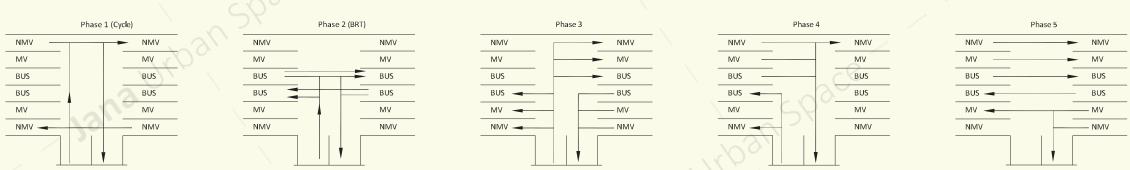
SIGNAL PHASE DIAGRAM



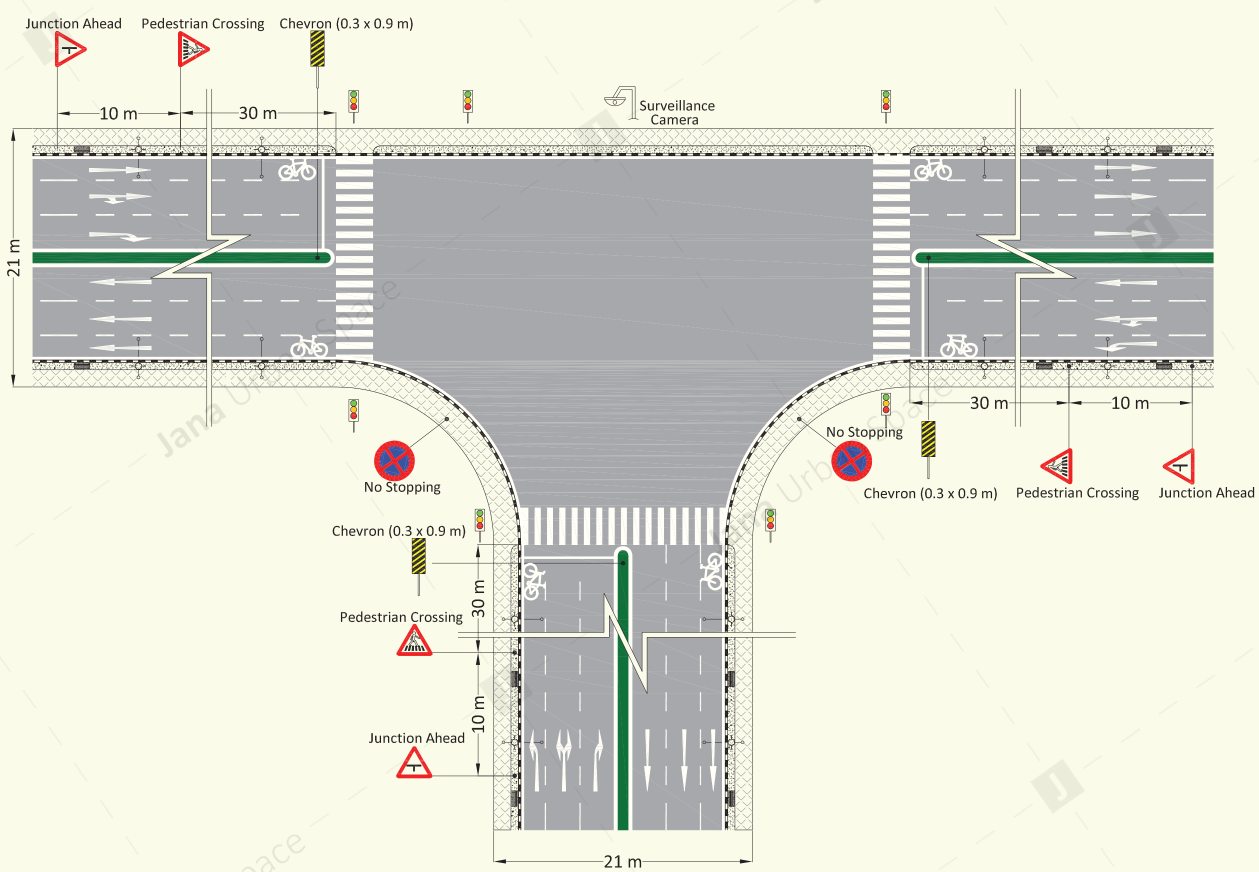
Sub-Arterial x Sub-Arterial - 3-leg intersection



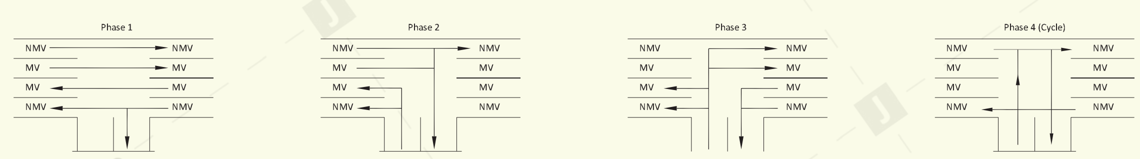
SIGNAL PHASE DIAGRAM



Collector x Collector - 3-leg intersection



SIGNAL PHASE DIAGRAM

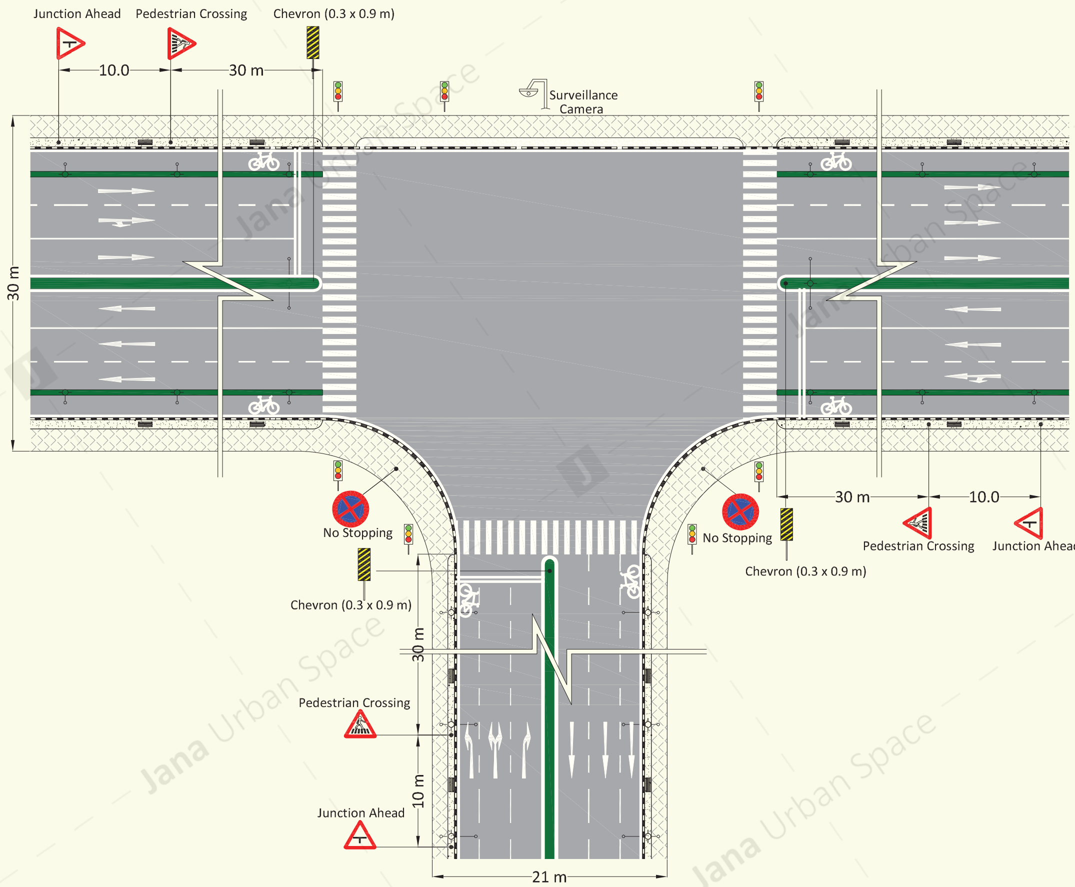


ref: Section 2.5.3

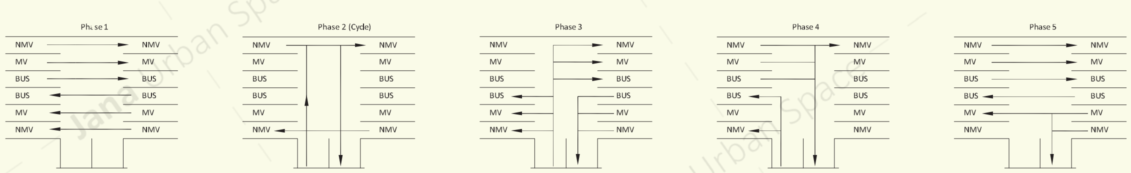
INTERSECTION DESIGN SPECIFICATIONS

TENDERSURE 2011 ed

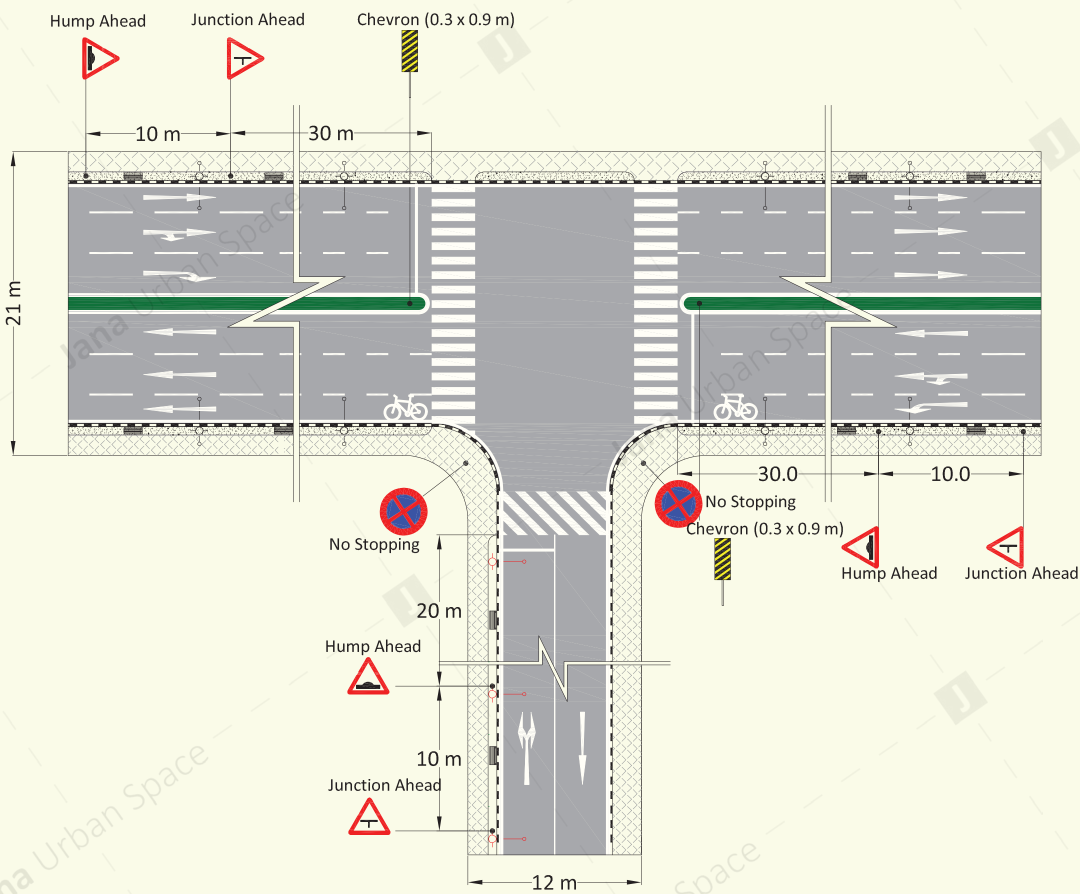
Collector x Sub-Arterial - 3-leg intersection



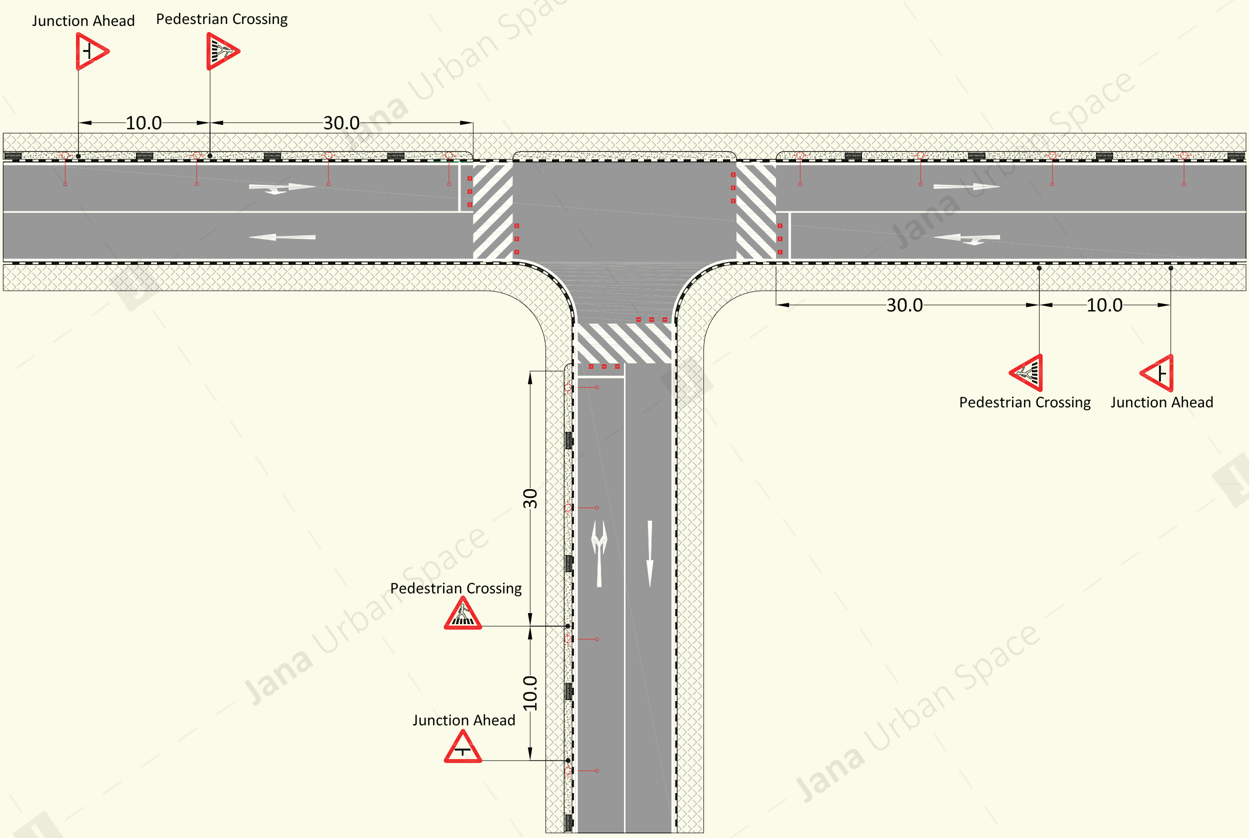
SIGNAL PHASE DIAGRAM



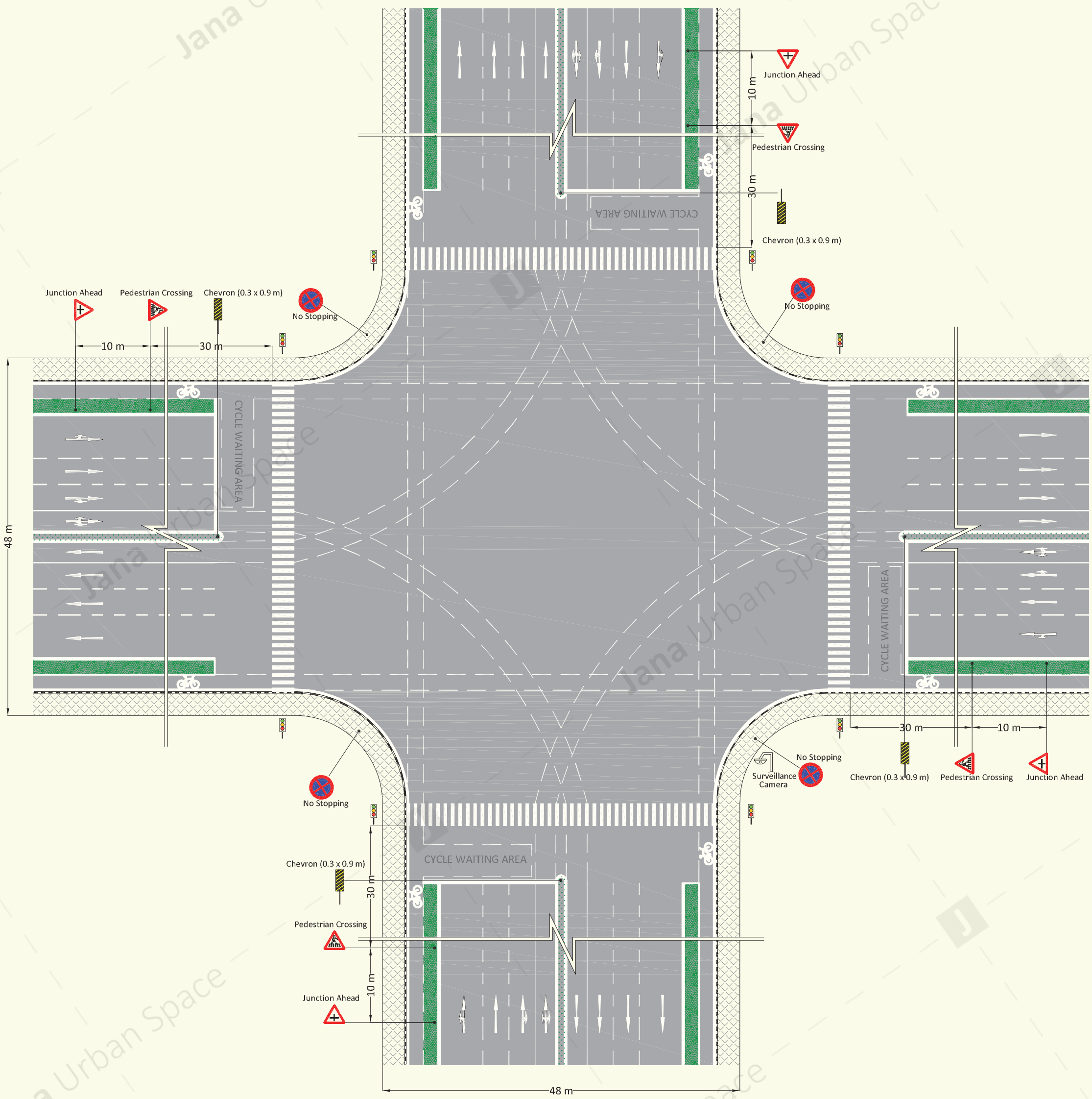
Local x Collector - 3-leg intersection



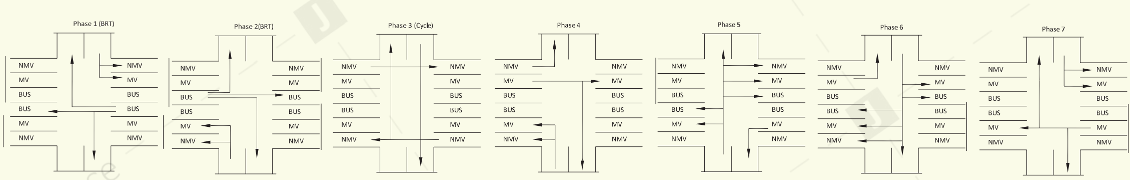
Local x Local 3-leg intersection



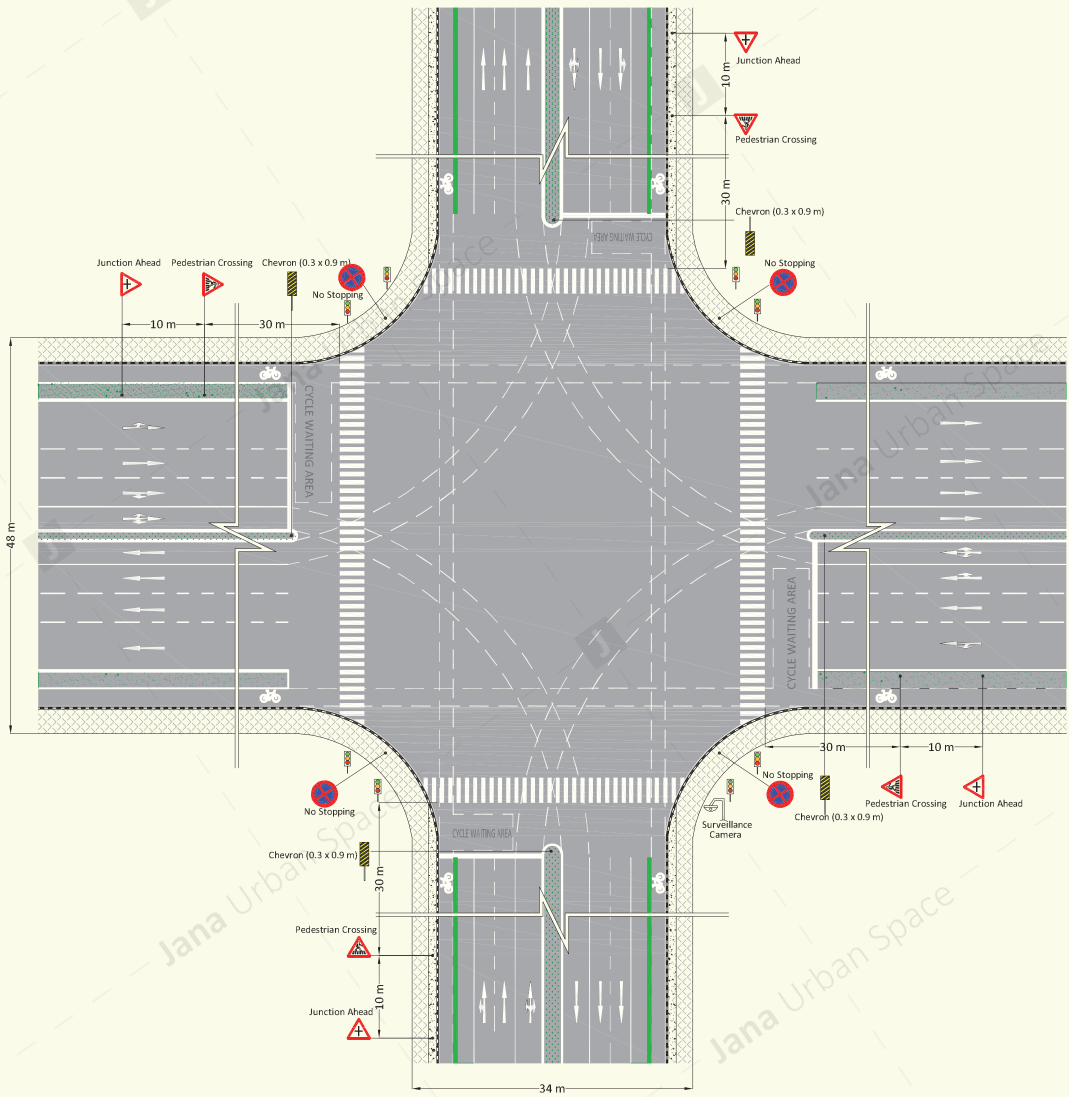
Arterial x Arterial - 4-leg intersection



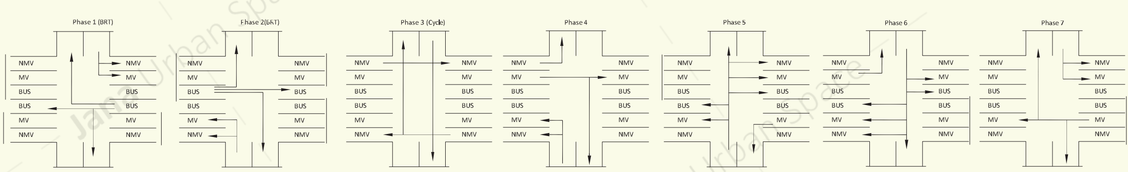
SIGNAL PHASE DIAGRAM



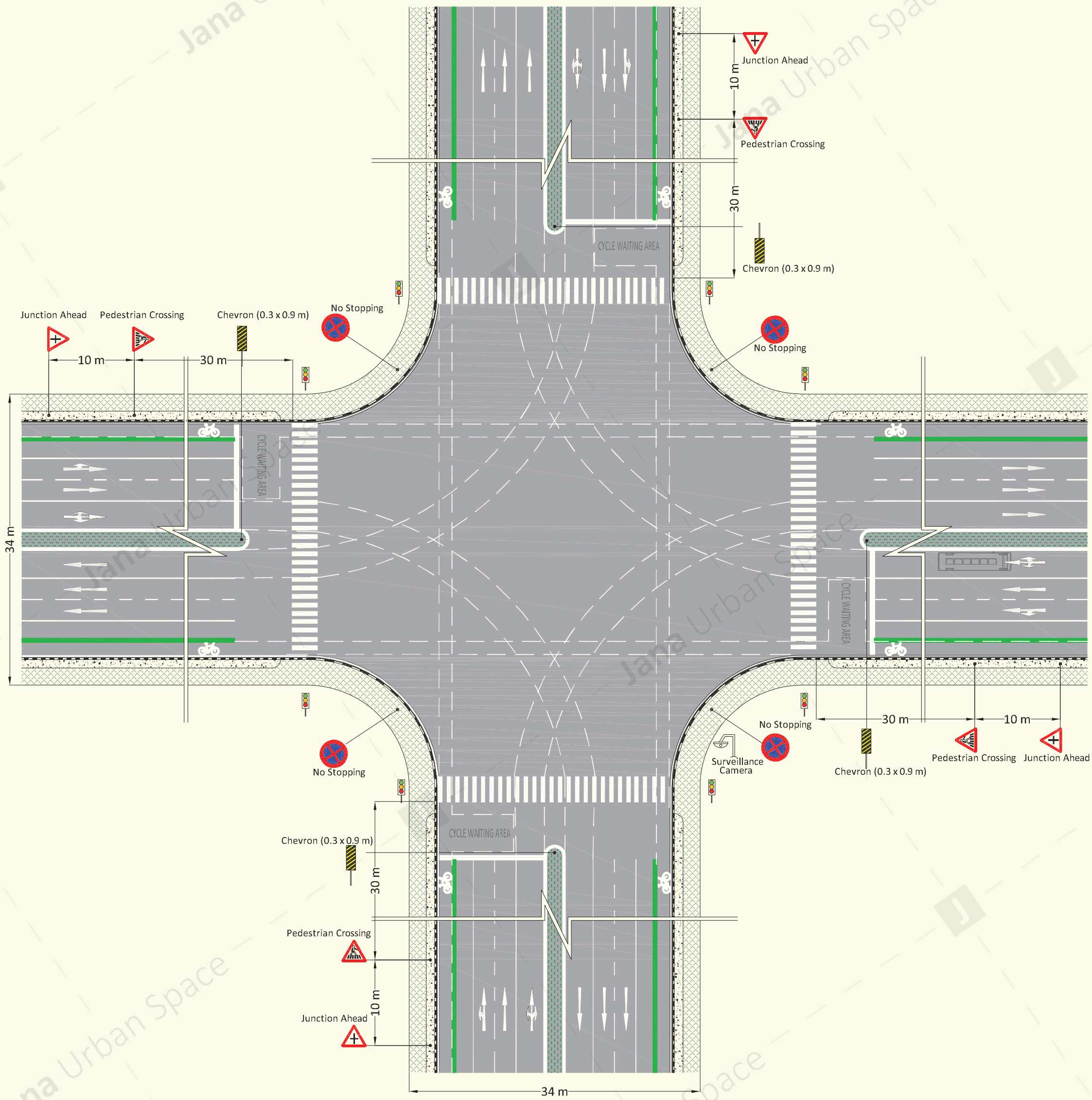
Sub-Arterial x Arterial - 4-leg intersection



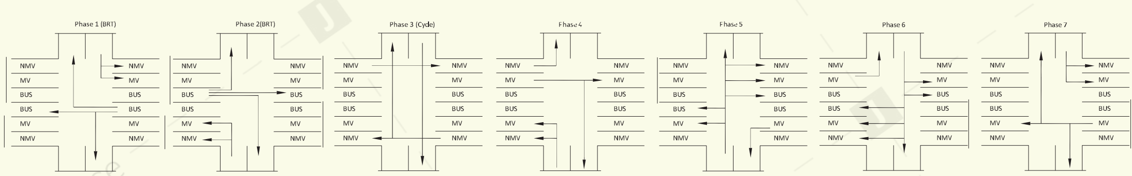
SIGNAL PHASE DIAGRAM



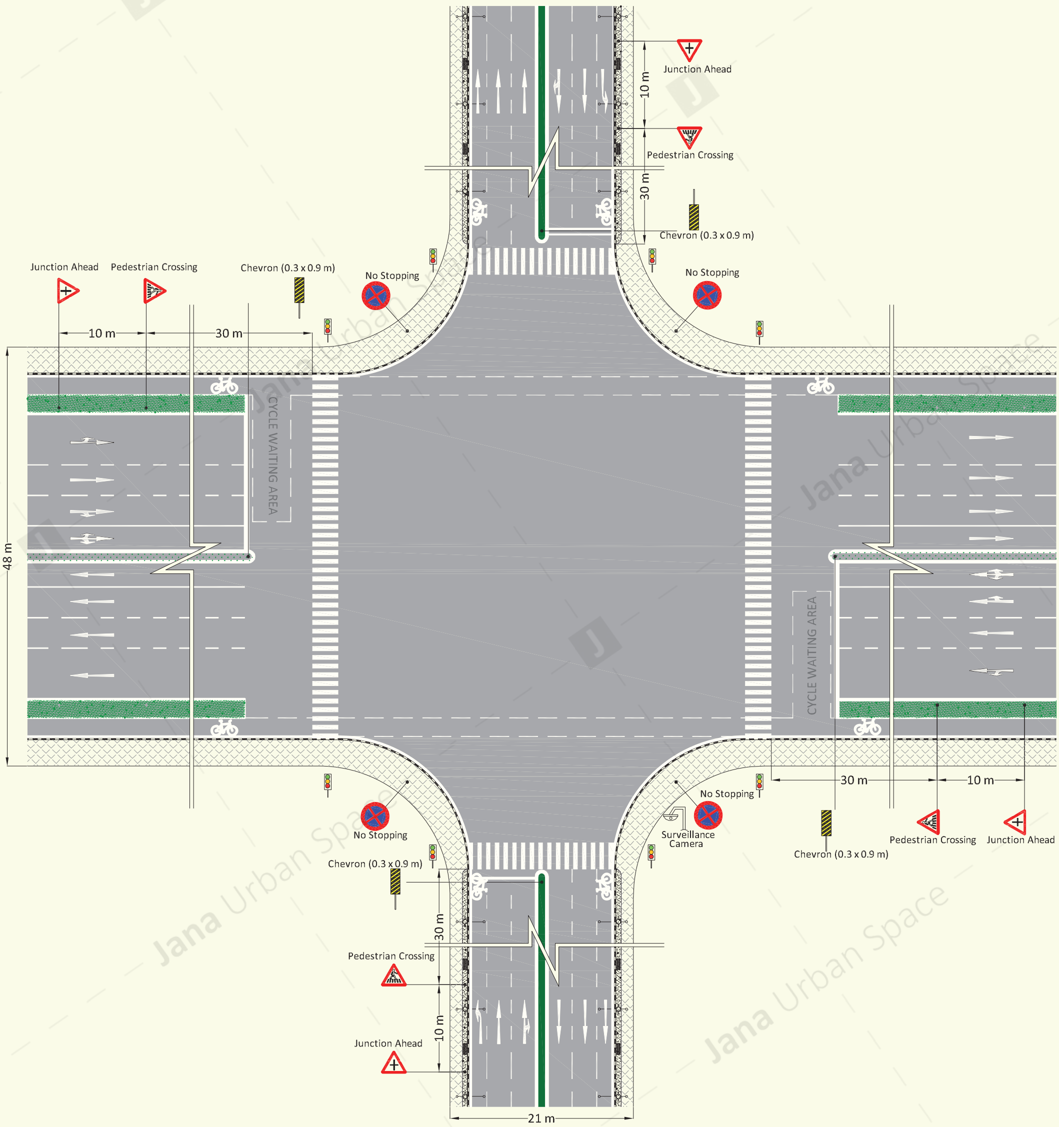
Sub-Arterial x Sub-Arterial - 4-leg intersection



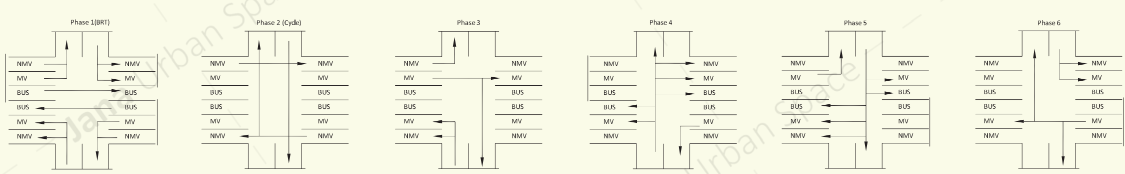
SIGNAL PHASE DIAGRAM



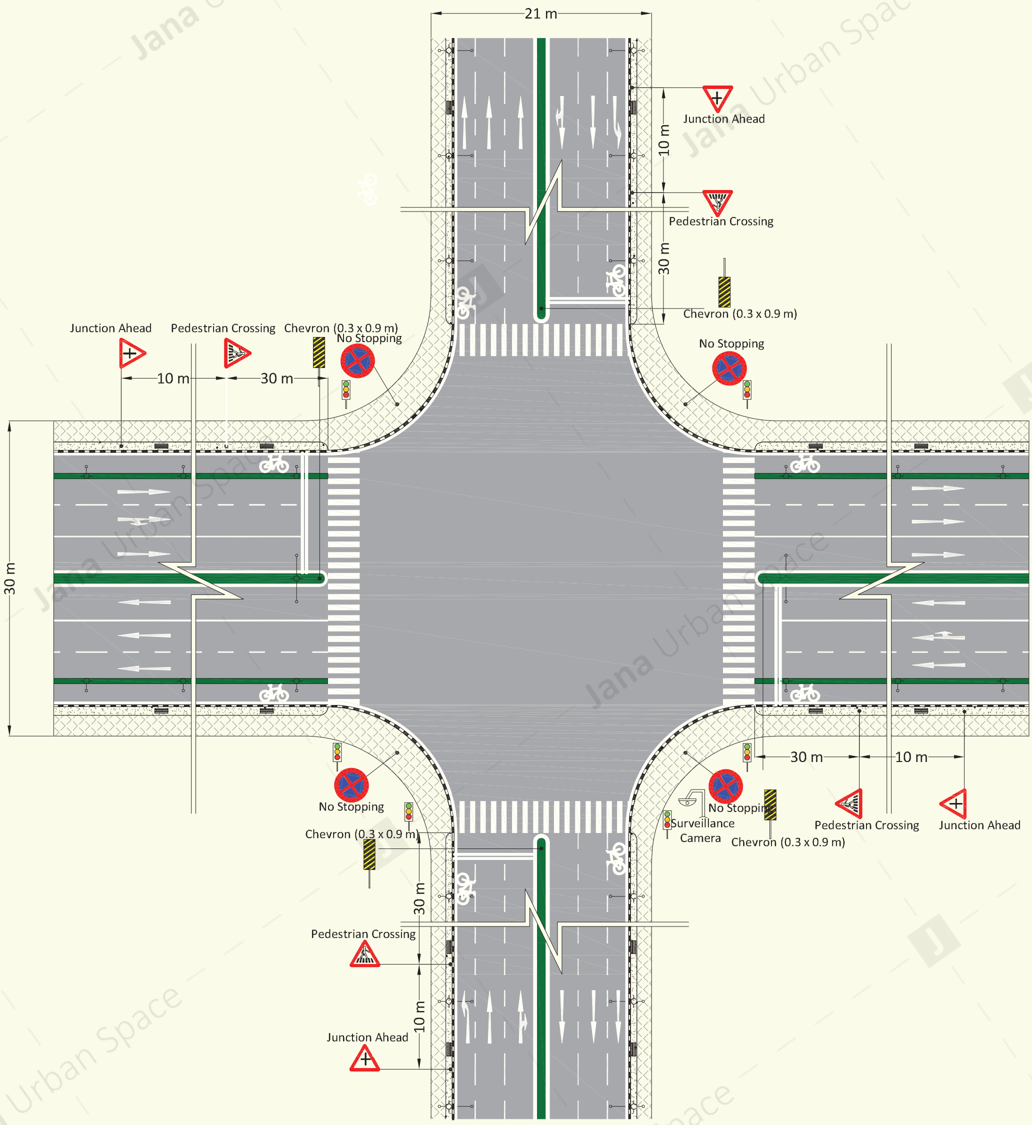
Collector x Arterial - 4-leg intersection



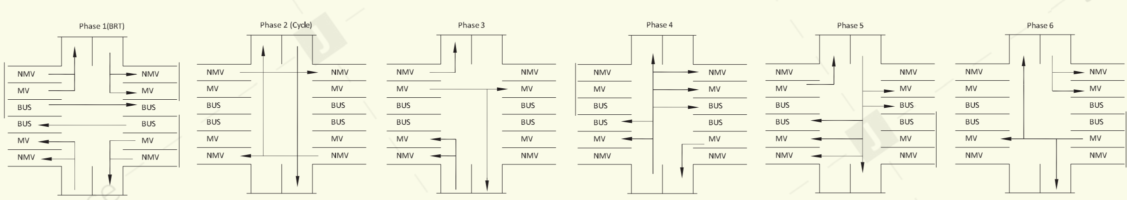
SIGNAL PHASE DIAGRAM



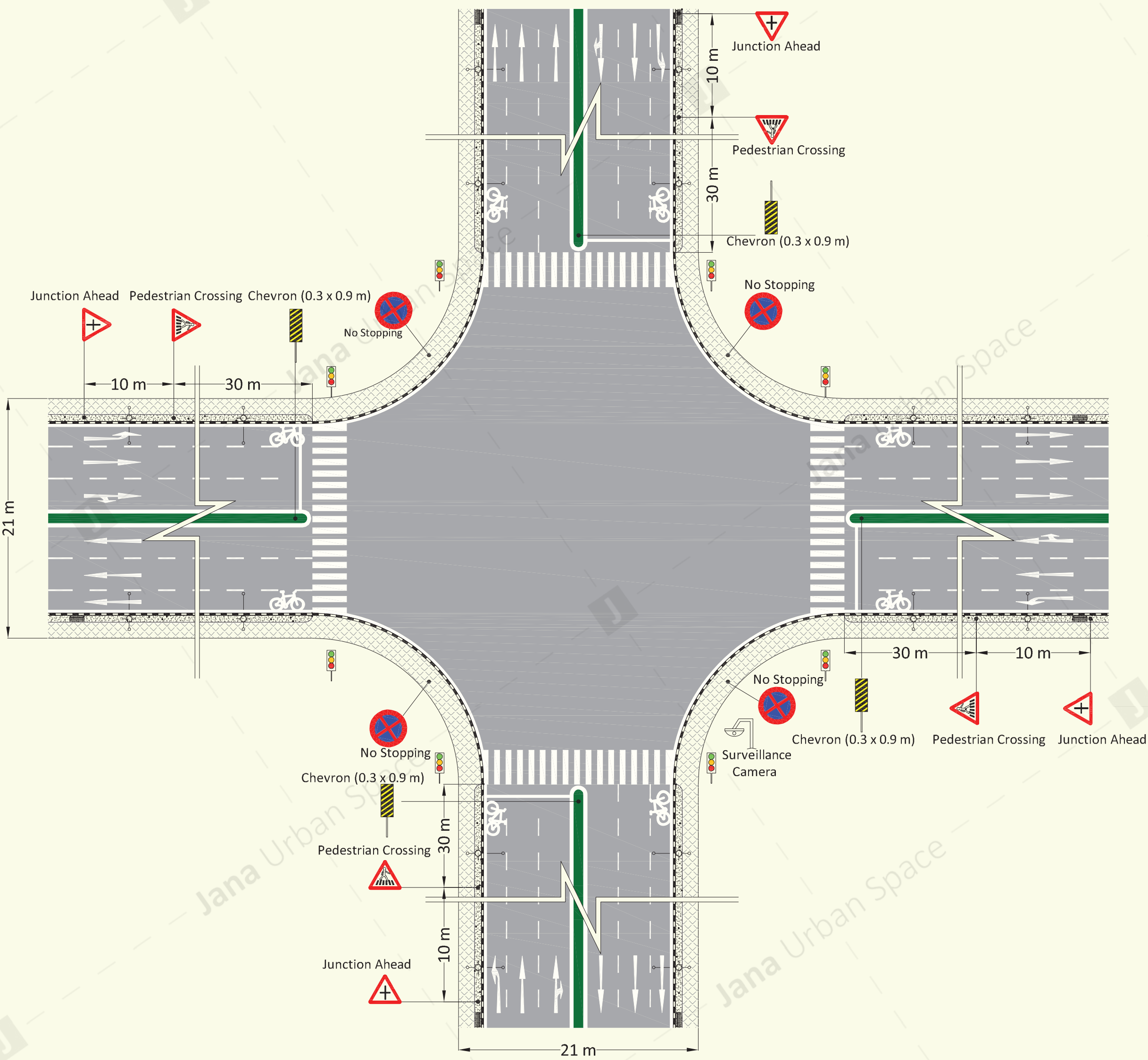
Collector x Sub-Arterial - 4-leg intersection



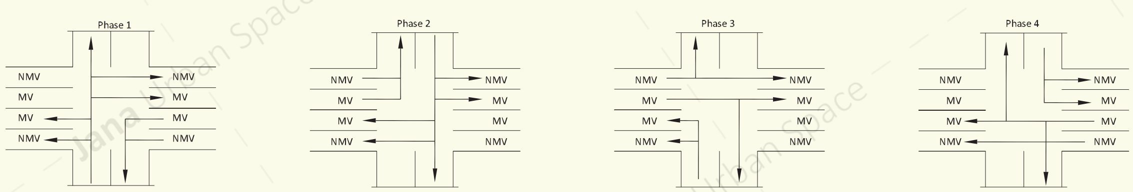
SIGNAL PHASE DIAGRAM



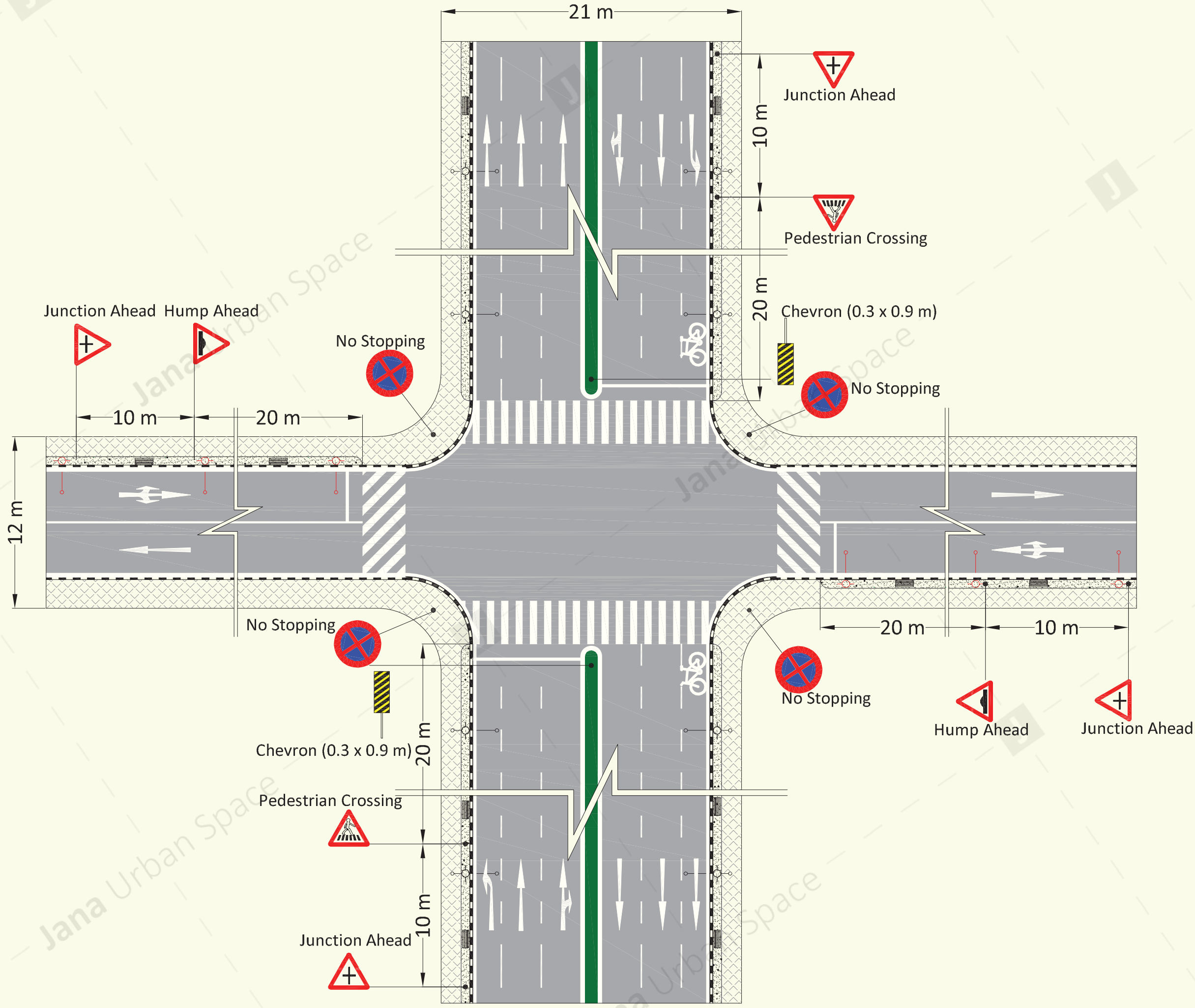
Collector x Collector - 4-leg intersection



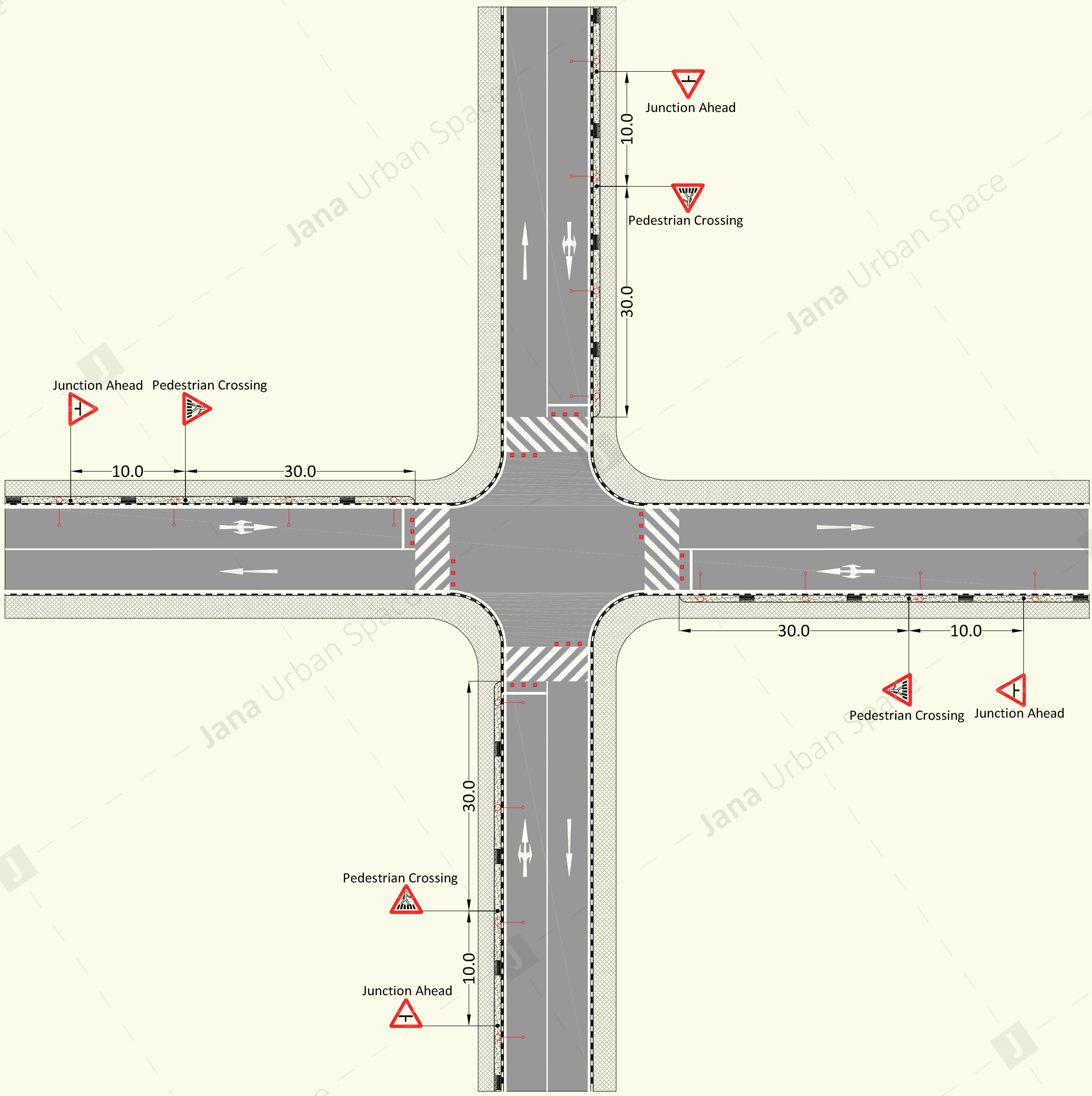
SIGNAL PHASE DIAGRAM



Local x Collector - 4-leg intersection



Local x Local - 4-leg intersection



2.8 >> Street Fixtures

(Refer plates 21 & 22, Pg 160 & 161)

Apart from carriage way, footpath, R-o-W comprises of above ground street fixtures like, street lighting, signs and signage, traffic signals, bus stops, parking, street furniture, bollards, waste disposal units and fire protection systems.

2.8.1 >> Streetlights

Streetlights provide night vision and safety for pedestrians and motorists alike. In recent times,the sodium vapour lamps are being replaced by the energy efficient LED lamps . Apart from consumption charges, most of the city corporation spends around INR 600 to 1000 per street light per annum as maintenance cost.

Thumb rule of illumination (refer fig below) generated by a street light on x and y axis is (1 x height) and (3 x height). The number of street lights required for a particular street is calculated by dividing the road length by spacing between each light.

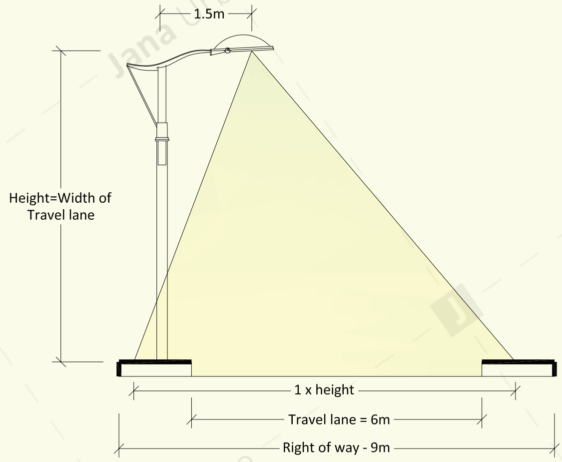


Image 2.54>> Streetlight illumination calculation (thumb rule)

Five types of streetlighting is adopted based on the site conditions, they are as follows:

1. ***Single-sided****:* Can be used only for local and sub local streets. The mounting height should be kept equal to width of carriage way and should be spaced at 3.5 to 4 times that of height.

2. ***Staggered****:* This is the most widely adopted street lighting in urban conditions. By staggering the spacing and mounting it on both sides of the street, the illumination is more even. Staggered streetlights are utilised in roads with three or more travel lanes.

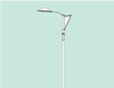
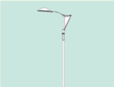
Height of street light should be equals to width of carriage way and should be spaced at 3 to 3.5 times height.

3. ***Central****:* Central mounting is adopted in highways and arterial roads, the major benefit of having lights in the central median is that, more light reaches the carriageway and footways. The mounting height should be 0.8 times the width of the carriage way and should be spaced at 3 to 3.5 times the height.

4. ***Opposite****:* Adopted in collector or sub-arterial street networks where there is no median. The mounting height should be 0.5 times the width of the carriage way and should be spaced at 3 to 4 times the height.

Table 2.12 indicates the recommended mounting locations for streetlights and their design dimensions based upon the street type. (Also refer images 2.77 - 2.80)

Table 2.12>> Recommended street light types for urban roads

Sl. No.	Street type	Recommended	Spacing (in m)	Staging Height (in m)	Drawing type
1	Sub-local	Single-sided	10	3	
2	Local	Single-sided	10	6	
3	Collector	Staggered/opposite	15	9	
4	Sub-arterial	Central	30	12	
5	Arterial	Central+opposite	30	12+6	

2.8.2 >> Bollards

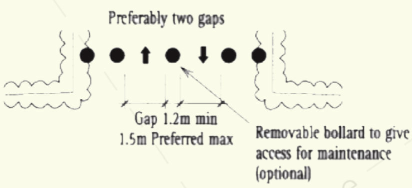
(Refer plates 23 & 24, Pg 162 & 163)

Bollards are used in two ways :

To protect pedestrian areas and public spaces from motorised vehicular movement.

To restrict access to heavy duty vehicles into residential areas.

The recommended spacing between bollards is 1.2 m – 1.5 m which is sufficient to deter motorcyclists while allowing wheelchair/prams access.



Plan 2.55 >>
Location and spacing of bollards

Image 2.56>>
Bollards in Europe

Image 2.57>>
Bollards for pedestrian crossing
(source: ahmedabadbrt.com)

2.8.3 >> Waste Bins

(Refer plate 22, Pg 161)

Waste bins may be provided at every 30 m in commercial areas and may be mounted on adjacent street poles. In residential areas, waste bins are not advisable due to foul smell and leads to mosquito breeding.

In recent times, most Indian cities have adopted household waste collection at the doorstep.

2.8.4 >> Public Toilets

The Ahmedabad BRT paper by CEPT university recommends 1 toilet block at every 1 km. These may be located along collector/ sub-arterial roads. Public toilets need to be integrated into the road design such that they are easily accessible and aesthetically integrated with the public environment. The toilets should not be placed on the pedestrian/ cyclists' path.

Provision of space for toilets may be made on R-o-Ws with pockets of extra space, on collector, sub-arterial and arterial roads, and at public spaces of high traffic. This will require an explicit public policy and budget.

Image 2.58 >>
Public toilet
(source: uttipec.nic.in)

2.8.5 >> Fire Protection System *(Refer image 2.75-2.80)*

Fire Protection Systems are essential in densely populated areas. Ideally, there should be a dedicated water distribution networked system for fire-fighting purposes. However in Indian cities so far, this is not the case, and it is only possible to connect the fire hydrants to the main water supply networks.

Fire hydrants must have two 65 mm (2-1/2-inch) hose outlets and one 115m (4-1/2-inch) suction connection with national standard fire hose threads. Wet-barrel hydrants are preferable in areas where there is no danger of freezing. Hydrants must be aboveground type. Hydrants must be installed adjacent to paved areas, accessible to fire department apparatus. Hydrants must not be closer than 1 m (3 ft) nor farther than 2.1 m (7 ft) from the roadway shoulder or kerb line. Hydrants must be installed with not less than 150 mm (6-inch) connection to the supply main, and valve provided at the connection. Barrels must be long enough to permit at least 450 mm (18-inch) clearance between the centers of the 115 mm (4- 1/2-inch) pump connection and grade.

Spacing Requirements

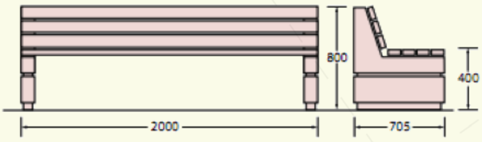
1. ***H***ydrant spacing must not exceed 182 m (600 ft) for housing developments without sprinkler protection. Hydrant spacing must not exceed 305 m (1,000 ft) for housing developments with sprinkler protection.
2. ***H***ydrants located adjacent to parking areas or bollards must protect other vehicle traffic areas. The bollards must be located so they are not directly in front of an outlet.

Image 2.59 >> Fire Hydrant installed adjacent to carriage way (source: localecologist.com)

2.8.6 >> Street Furniture

Street benches may be housed in utility strips without causing an obstruction for the pedestrians/cyclists at regular intervals where people can rest and interact.

Street furniture and other street design elements that are static (including utility boxes, street lighting, trees, parking, bulb-outs), need to be aligned properly in order to leave adequate clear width for the mobility of pedestrians, cyclists, and motor vehicles.



Typical design of a street bench

1. ***O***n a 3 m wide footpath, furniture and amenities should be provided sparingly and along the tree line while maintaining a minimum of 1.5 m clear space for walking.

2. *A* parking or service lane discontinued in the vicinity of a bus stop provides space for street vending and furniture.

3. *O*n a shared street, furniture can be placed on islands that double as traffic calming elements.

Image 2.60 >>
(source: streetsblog.org)

Image 2.61 >>
(Source: ITDP)

Image 2.62 >>
(Source: ITDP)

2.8.7 >> Transformers & Electrical RMUs

RMUs, telecom boxes and transformers litter urban roads, hindering all mobility, especially for pedestrians. Out of 28,704 transformers in Bangalore, 22,410 (78%) transformers are located on public roads and footpaths. Urban public utility departments must be legally bound to conform to standards that protect the rights of pedestrians and other road users.

Image 2.63>>
Transformer blocking pedestrian path

2.8.8 >> Outdoor Advertisements

The proliferation of billboards in the urban centres is reaching epidemic proportions and it is important to set up specific standards that regulate the advertisements and hoardings to make the urban public spaces clutter-free. In comparison to the developed nations, India lags far behind in controlling the display of garish advertisements and hoardings despite the fact that most of these are illegal. In western cities, there are severe restrictions and proper control regulations including skyline assessment tosafeguard the natural landscape and preserve its natural beauty. Though the revenue

Image 2.64 >> Hoardings on the street

generated by the billboards and advertisements cannot be ignored, its contribution to the increasing visual pollution and related traffic hazard is of serious concern. Thus it becomes imperative to develop design standards for all public advertising that takes the following into consideration:

1. ***Z***one wise demarcation of the city and specifying the type and size of advertisements that can be displayed in a particular zone. Areas of special historic and architectural interest, institutional areas and public parks should be devoid of any advertisements.
2. ***T***he size, design, location and degree of illumination of advertisements should take into consideration the character of the area so that the advertisements do not adversely affect the visual appeal of the area.
3. ***R***estriction should be imposed in displaying advertisements on R-o-Ws and traffic junctions/circles that can pose a serious pedestrian/traffic hazard.
4. ***T***he illumination arrangement of the advertisements should not cause any disturbance to traffic. Bright glaring and blinking advertisements should be restricted near traffic junctions or places where they can cause a visual distraction to drivers.
5. ***P***rocedure should be developed for proper skyline assessment, as done in the western cities, to define a rationale for permitting advertisement and hoardings.
6. ***T***he advertisements displayed should be maintained in a proper and safe manner.
7. ***I***llegal hoardings should be removed and only those permitted by the Corporation should be allowed to be displayed. In Indian cities,

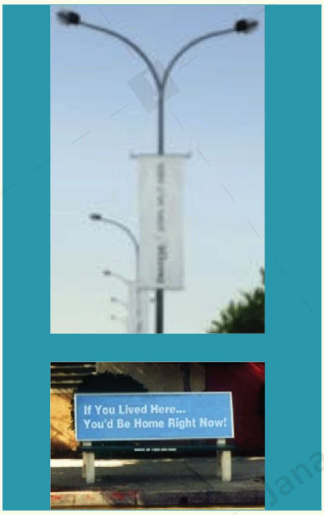


Image 2.65>>
Outdoor
Advertising

the number of illegal hoardings far exceed the ones that are permitted, thus this requires removal of the illegal hoardings in a phased manner.
8. *P*enalty clauses should be specified in the standards and any violation to the standards should be heavily fined.

While the specific standards are left to each municipality to devise, the following specifications may be used by the municipality to assess the applications for the erection of advertising signs:

1. *A*dvertising signs are not permitted in areas where they are likely to cause a visual distraction to motorists, obscure or compete with road signs, interfere with sight lines or detract attention at a junction.
2. *T*he erection of advertising signs and free standing hoardings are not permitted on the major urban routes.
3. *S*igns are not generally permitted in residential areas, on or near buildings of historic/architectural merit, in amenity areas or where they could interfere with protected views.
4. *S*igns, which are attached to buildings, are preferable to those on free-standing hoardings. Box type signs are prohibited and spotlighting is in general more acceptable than internal illumination.
5. *A*dvertising signs should be sympathetic in design and colour both to their surroundings and to the buildings on which they are displayed.
6. *T*he size and scale of advertising signs should not conflict with existing structures in the vicinity. Signs should not interfere with windows or other features of a façade or project above the roofline.
7. *S*igns should be integrated with the streetscape and not be visually intrusive or numerous.
8. *S*ignage above first floor sill level should be severely restricted to avoid clutter.
9. *A*ll external lighting should be subdued and directed away from the public roadways

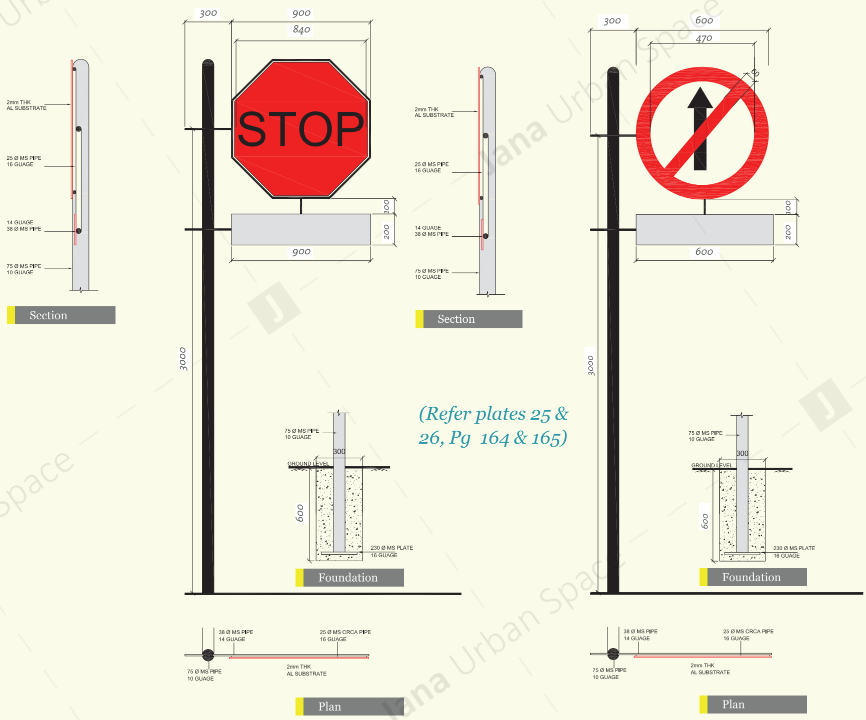
2.8.9 >> Traffic Signage

(Refer plates 25 & 26, Pg 164 & 165)

i. Traffic Signage

Traffic signs for India are prescribed in Motor Vehicles Act, 1988. State governments are responsible to install traffic signs as prescribed in the act.

Importance of traffic signs:
1. *R*oad safety rules.
2. *S*peed and direction of movement allowed
3. *W*arnings of potential hazards
4. *D*estination, direction and distance to destination.



(Refer plates 25 & 26, Pg 164 & 165)

Commonly used signs and markings:

Some of the important commonly used signs, as per IRC:67-2001, are listed below:

1. ***Mandatory* / Regulator Signs**: The most recognizable sign on any road is the stop sign. The sign is always bright red and octagon-shaped. It is generally positioned at intersections, and drivers are required to come to a complete stop behind the line or crosswalk that it protects. Pedestrians have the right-of-way at a stop sign.

‘**S**top’ and ‘Give Way’ signs
‘**N**o Parking’ and ‘No Stopping’ signs
‘**S**peed Limit; and Vehicle Control’ signs
‘**N**o Overtaking’ signs
‘**C**ompulsory Direction Control and other signs

A yield sign is a triangular sign with the word "yield" lettered on it on a white background. It is placed at an intersection at which a driver is not required to stop, but instead must proceed cautiously. Yield signs are also placed at the point where cars merge onto the freeway. STOP or GIVE sign to be located at the point where vehicle is required to stop or as near it as possible, approximately 1.5 m - 3 m. Where there is a pedestrian crossing the stop sign is to be erected 1.2 m in advance of the pedestrian crossing or stop line.

2. **Cautionary/warning signs:** Warning signs are placed at different places on the road to let drivers know of an upcoming change in driving conditions. These signs are shaped like a diamond and provide instruction regarding a change in the speed limit or a sudden curve in the road. These signs serve to warn drivers, but they do not regulate any specific action.

Curve signs
Narrow Bridge / Narrow road
Road widens
Gap in median
Pedestrian crossing
School
Men at work
Cross road / side road
T-Intersection / Y-Intersection
Major road ahead
Roundabout
Unguarded Railway Crossing
Speed Breaker
Reduced carriageway

Usually the warning signs should be placed at the distance of 50 m in advance from the intersection. Junctions where additional emphasis is required because of high speeds and/or high accident rates, warning signs may be located at 200m distance in advance.

Image 2.66 >>
Traffic signage
in Europe

3 . ***Informatory Signs:***

Signs that convey messages of information, guide motorists with landmarks and directions to destinations.

a) ***D***irection and place identification signs
Advance direction signs
Destination sign
Place/City identification

b) ***F***acility Information signs
Public telephone
Filling Station (Petrol Pump)
Hospital
Resting Place

c) ***O***ther useful information signs
Airport
Bus stop

The general color scheme for the traffic signs shall be as mentioned in IS:5. The colors shall be durable and uniform of an acceptable hue when viewed in daylight or under normal headlights at night. (Refer to IRC 67 or BATF/BBMP road signage manual 2000.)

Sl.no	Colour	Standard	Particular	Colours
1	Blue	IS Colour	No. 166: French Blue	
2	Red		No. 537: Signal Red	
3	Green		No. 284: India Green	
4	Orange		No. 591: Deep Orange	

ii. ***Location of Traffic Signs***

The signs shall be so placed that motorists and pedestrians can recognize them easily and in time. Normally the signs shall be placed on the left hand side of the road. As per the IRC standards, the signs should be erected not less than 60 cm away from the edge of the kerb in case of kerbed roads and at a distance of 2-3 m from the carriage-way edge in case of unkerbed roads. Mounting height suggested is 1.5 m for unkerbed roads and 2 m for kerbed roads.

The signs and shall be so placed that they do not obstruct vehicular traffic on the carriageway, and if placed on the shoulder/footpath/refuge island, should not obstruct pedestrians.

iii. *Orientation of Signs*

The signs shall be placed at right angles to the line of the approaching traffic. Signs relating to parking of vehicles and stop signs are to be placed at an angle between 30 and 45 degrees to the direction of traffic flow while ensuring there is no glare effect. On horizontal curves, the signage is to be determined with regard to the course of the approaching traffic.

Signage faces may be tilted upward/ downaward at road gradients visible to approaching traffic.

iv. *Traffic control and surveillance cameras*

Many developed countries use surveillance camera systems to capture public miscreants involved in illegal action/crime. These surveillance camera systems also serve to capture traffic violations, unusual events and occurrences. Traffic Management Centres (TMC), run by the traffic police, are vital centres to monitor, evaluate and redirect traffic flows. TMCs are linked to a network of surveillance cameras strategically placed at road intersections, high traffic/accident areas, public gathering space,etc.

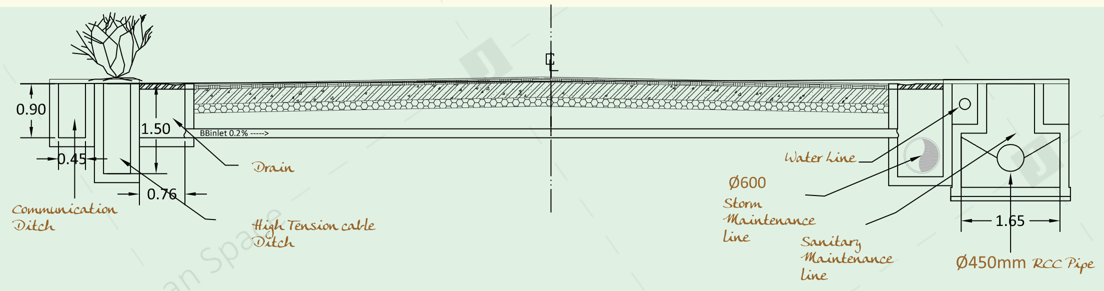
Electric wiring and supply is a key requirement for continuous data flow and this can be linked to the traffic light network where possible.

Image 2.67 >>
Surveillance Camera
used by BTP

2.9 >> Below grade utility network design standards and specifications

(Refer plate 29, Pg 168)

The 4 key networked utilities that run alongside the raod network in main trunks, distributor arteries, and last-mile links, are : water; drainage, sewage and power. To these four key utilities is added the ICT network termed as the fifth utility. In some countries, cooking and heating gas supply is provided through a networked utility. In India, however this is not a common practice.



Section 2.68>>
Drawing representing below grade utilities
(Source: Invicus Engg)

Urban roads are constantly cut up by various agencies installing or servicing these networks. Given this peculiar vulnerability of roads, there are two interventions recommended:

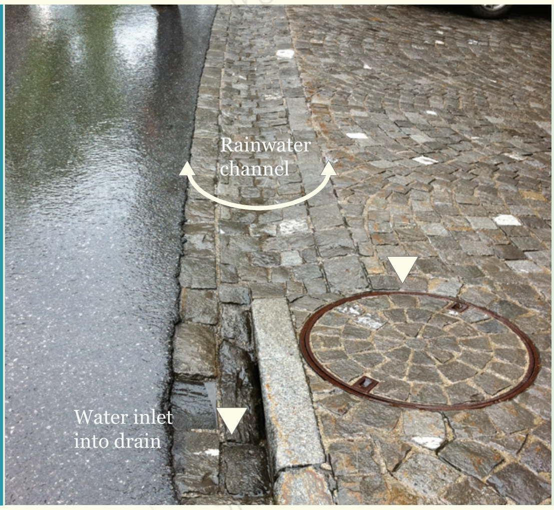
1. ***F***irst, to provide dedicated space and easy access to below-grade utilities;

2. ***S***econd, to specify road surfaces that facilitate easy repair and maintenance. (see table 2.13)

Table 2.13 >>
Road types and recommended surfaces

Road type	Expected frequency of cuts to road	Recommended Surface	Ease of maintenance to servicing network
Sub-local	High	Cobble-stone	Good, low cost
Local	Very high	Cobble-stone	Good, low cost
Collector	Moderate	Asphalt	Fair, mid-cost
Sub-arterial	Low	Asphalt/Concrete	Difficult, high cost
Arterial	Low	Concrete	Difficult, high cost

Image 2.69 >>
Detail of rainwater trough and manhole set in paved footpath
(Refer Plate 31, Pg 170)



2.9.1 >> Sewer/Drainage, Water Supply Lines

(Refer plate 32, Pg 171)

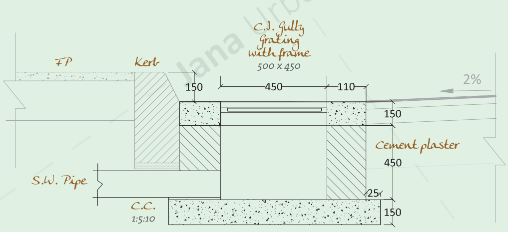
Sewage lines are to be laid at a substantial depth below grade and ideally located away from water and rainwater drainage networks to avoid accidental contamination.

Sewer and drain lines are to be laid at an appropriate incline that encourages gravitational flow from local to trunk lines within the networked hierarchy.

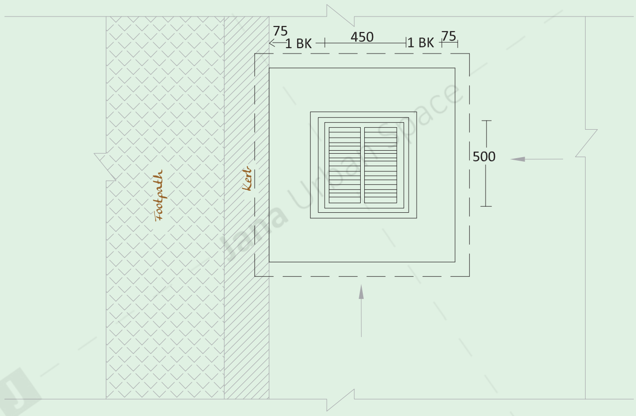
Water lines are maintained under pressure and are to be laid away from the road traffic areas so as to avoid damage to the surface due to any leakages.

The Indian Roads Congress (IRC: 98-1988) recommends a depth between 2.0 m to 6.0 m for a 'trunk sewer line' and a depth of 1.0 m to 1.5 m for a 'trunk water line' and 0.6 m to 1.0 m for 'service water line'.

Roads also serve as a channel for rainwater directing it into shoulder drains below the footpath leading to the side drains which then directs the water through culverts below the road surface and then onto the main storm water drains.



Cross-section of Horizontal Grating



Plan of Horizontal Grating

Section 2.70 >>
Drawing representing below grade utilities
(Source: Invicus Engg)

It is important that rainwater is properly channeled away from the road surface since water erodes the bitumen surface of the road creating damage and potholes. The kind of inlet that is required for a particular area needs to be arrived at after detailed hydraulic design for the road. Once the storm water is collected from the street surface by an inlet, it is directed into the storm water drainage system. The storm water drainage system comprises of laterals, main trunk, outfalls and other appurtenances. The storm water thus collected must be protected from contamination of urban waste and open sewage let into these storm water drains and only then discharged into lakes.

Water lines are no longer to be located under road surfaces since they need frequent access for repairs and maintenance. Instead, a dedicated space must be earmarked by the side of the traffic area alongside the drain with access points at valves and line junctions.

Image 2.71 >>
Storm water drain in a Collector Road

2.9.1.1 >> Swales

Swales are linear depression of channels that provide for stormwater collection and conveyance. Swales may simply be grass-lined or more densely vegetated and/or landscaped. They direct stormwater across grass or similar ground cover and through the soil, slowing the movement of water.

Swales can reduce storm water run-off volumes and peak flows. Grass or other vegetation (such as rushes) is used to carry out this function. Examples of swale use are in road medians and verges, car park run-off areas, parks and recreation areas. Swales are simple to maintain and can fit well in any urban design.

The length of the swale is generally equivalent to that of the contributing impervious area. The runoff enters the dry conveyance swale as lateral sheet flow and the total contributing drainage area cumulatively increases along the length of the swale.

Bores or aquifers may also be set at regular intervals along the swale trench. A portion of the filtered stormwater may be conveyed to these aquifers and stored beneath the site for subsequent reuse for landscape irrigation.

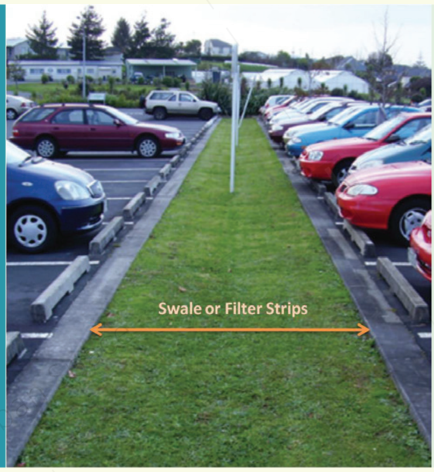
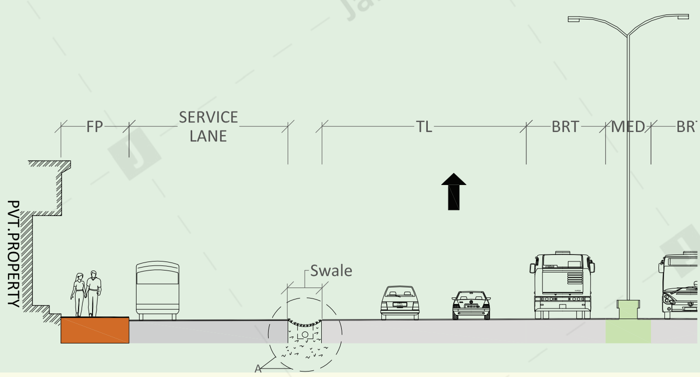


Image 2.72 >>
Swale

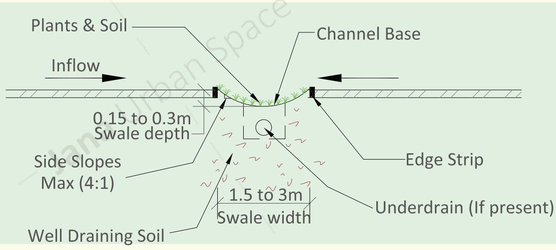
Swales are recommended beyond 48m width of the road. It must be provided all along the length of the road, however the components of the swale need proper design and planning. Following are the components of a swale:

1. ***Inflow points***: Stormwater flow entry, via pipe outlet or surface runoff
2. ***Side Slopes***: Total channel width. Slope less than 4:1 for mower access and to prevent scour
3. ***Channel Base***: Low flow path, may have gravel or rip rap reinforcing to prevent erosion
4. ***Underdrain (if present):*** Usually perforated pipe buried under channel to capture filtered flow and connected to stormwater system
5. ***Plants and soil:*** Grass or other low lying plants in permeable soil for filtering stormwater

Section 2.73 >>
R-o-W scenario
showing Swale



Detail at "A"

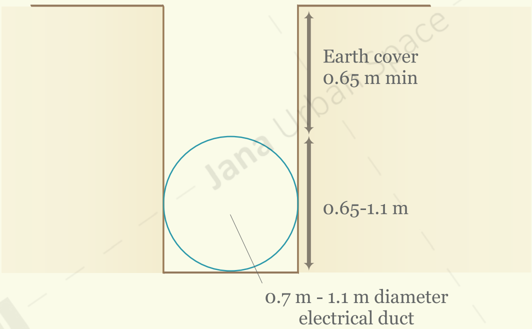


2.9.2 >> Electricity

Electricity cables are of different types, Low Tension (LT) cables and High Tension (HT) cables. These cables should be located away from water supply lines, ICT lines and trees to prevent short circuits, electrical interference and damage by tree roots. The width of electrical ducts will vary between 0.7 m to 1.1 m depending on the number of cables they are meant to house. They must be laid at a minimum depth of 0.65 m upto a depth of 1.1 m with a minimum earth cover of 0.65 m.

Overhead, high-risk HT cables must be placed with care, away from pedestrians and traffic areas ideally over medians and along the side of the road network with restricted access to the land below.

Underground Electrical Cable Trough



2.9.3 >> Gas Pipelines and those carrying combustible materials

Pipes carrying combustible materials should be located far away from electricity cables and sources of heat. The Indian Roads Congress (IRC) recommends laying of such pipe lines at a depth of 2.0-3.0 m in IRC: 98-1988 with the following technical specifications:

1. ***T***he pipelines are generally to be laid at a depth of 1.2 m in the form of steel pipes having a diameter of 12 inches to 16 inches.
2. ***T***he life of these pipes is around 30 years and should be replaced after that.
3. ***O***ptical fibers are laid in the trench along with the gas pipelines to monitor the gas supply network.
4. ***I***solation valves are provided at every 2.5 km for maintenance, so that the particular stretch could be isolated from the rest of the network for maintenance purpose.
5. ***T***here is a future proposal for the isolation valves to be operated through remote control from a central control station.
6. ***G***as lines may be laid below the existing utilities.
7. ***D***istribution lines from the trunk lines are made of Polyethylene and have a pressure rating of maximum 26 bars.
8. ***G***as lines should not be laid parallel to High Tension (HT) lines. In case HT lines are in the proximity, the gas pipe lines are at a minimum

case HT lines are in the proximity, the gas pipe lines are at a minimum of 400-500 mm away from the HT lines.

9. *T*he trench size required to be dug for laying gas lines is 300 mm x 300 mm.

10. *A*n RCC utility duct 300 mm x 300 mm in size is usually provided to cross lines beyond an existing roadway.

2.9.4 >> Optic Fibre Cables (OFC) for Information, Communication, Technology (ICT)

(Refer plate 33, Pg 172)

The optical fibres are conventionally laid down by two methods:

The **conventional trench method** is used to lay OFC cables below sandy surface, away from the main carriageway. The trench is usually 1.65 m below the road surface, with minor variations in depth because of local site conditions.

The **direct buried cables (DBC)** are laid at a depth of 165 mm below the road surface. The cables are laid in a continuous stretch with access provided at every 4 km for service requirements. Within each 4 km stretch, pool boxes at a distance of 1 km spacing provide access to the OFC lines.

IRC-98 guidelines emphasize the need for constructing ducts to place networked utilities below the road surface. The IRC guidelines recommend advanced planning to earmark the position of each utility line expected along the road, and to provide space in a manner such that work on any utility does not interfere with other services or the safe functioning of the road.

While forming new layouts the concept of common utility duct or multi utility duct is recommended, based on the type of road ; the RCC duct size and prevailing conditions. These ducts are to be laid at the outer edges of the travel lane area. The recommended depth for the utilities are provided in Table 2.14.

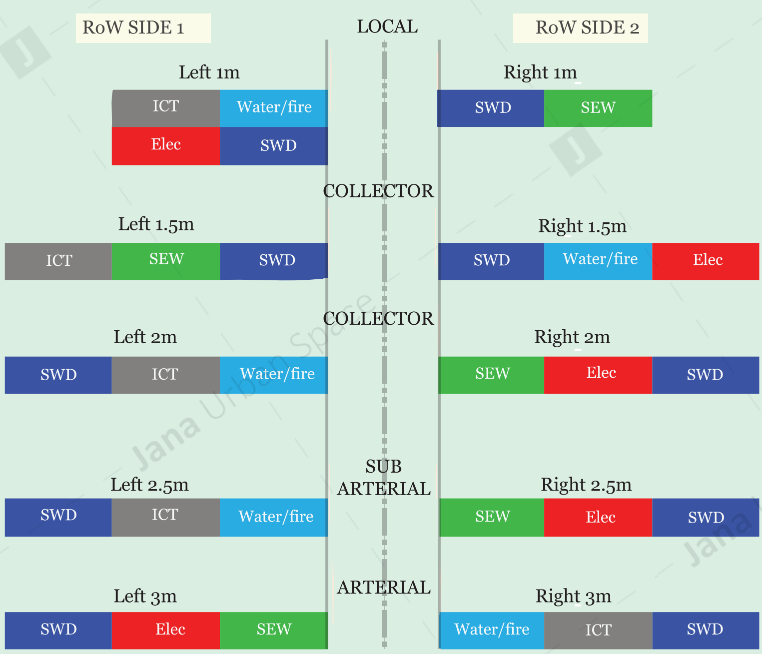
Image 2.74 >>
Conventional trench, Bangalore
(Photo: K Jaipraasadh, KRDCL)

Table 2.14 >>
Recommended below-grade depths for various utilities

Sl. No.	Service	Depth (in m)
1	Trunk sewer line	2-6 m
2	Water supply line	
	Trunk line	1-1.5 m
	Service line	0.6-1 m
3	Electric cable	
	High Tension cable	1.5-2 m
	Low Tension cable	0.6- 1.3 m
4	Gas main and ducts	2-3 m
5	OFC	
	Directly laid	0.6-1 m
	Laid in ducts	1-2 m

Ducts are designed based on number of variables like, topography, type of road, footpath width, type of soil, available slope, etc. A quick schematic reference for below-grade utilities is shown in the Image 2.75 and organised by the classification of urban road types.

Image 2.75 >>
Placement of Utilities in ducts based on: Classification of Road; available width



Left

Right

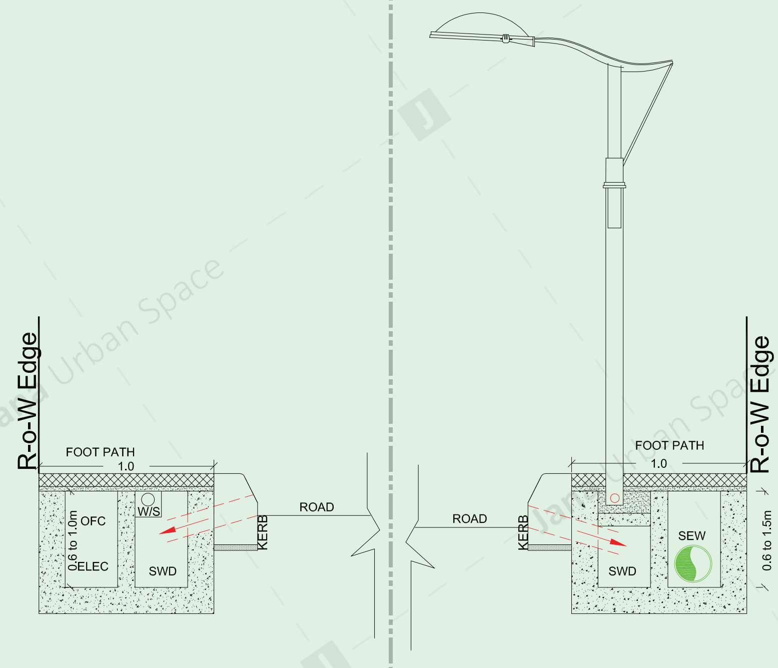
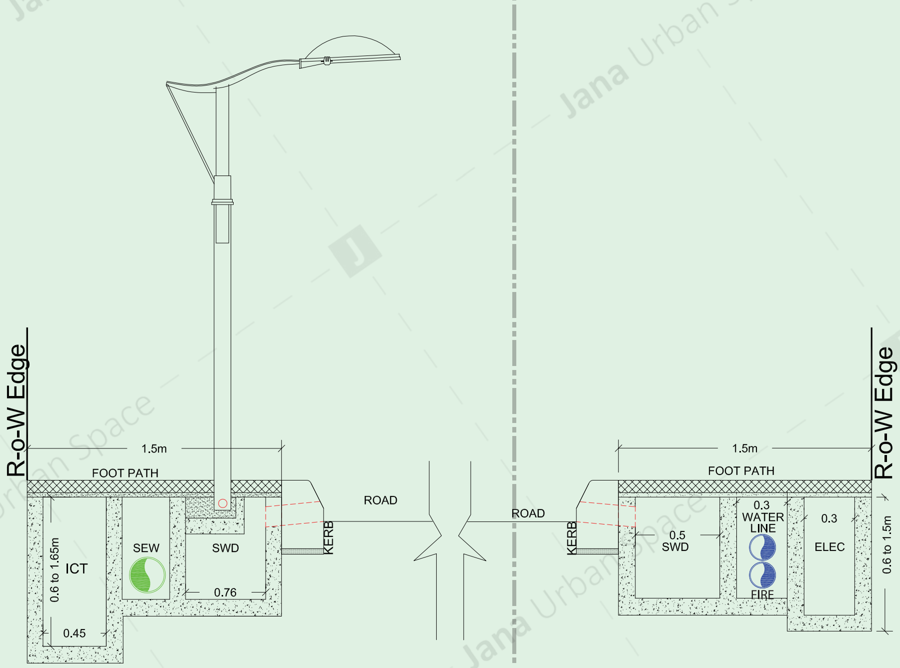


Image 2.76 >>
1m wide footpath
Utilities – SWD, Power line, OFC, local water supply, sewer line

Image 2.77 >>
1.5m wide footpath
Utilities – SWD, Power line, OFC, local water supply, sewer line



Note: the utilities guidelines for each side can be mixed and matched to the width of the footpath on the ground

Image 2.78 >>
2m wide footpath
Utilities – SWD, Power line,
OFC, local water supply, sewer line

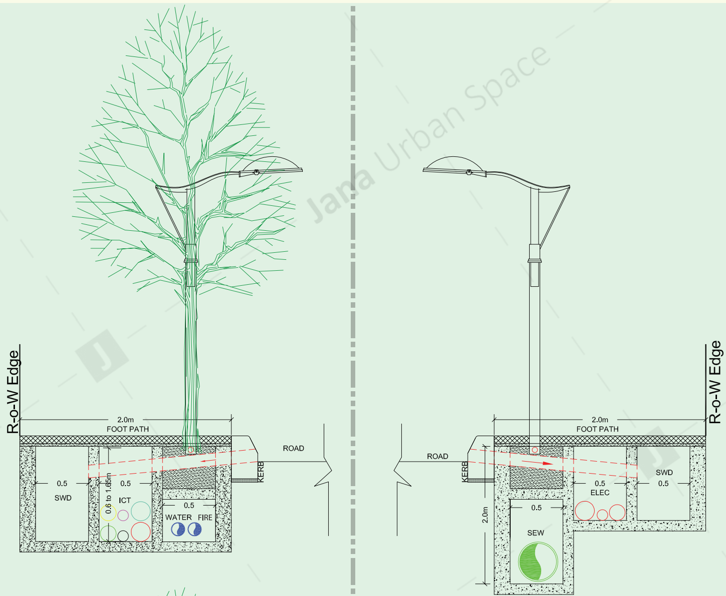


Image 2.79 >>
2.5 m wide footpath
Utilities – SWD, Power line,
OFC, local water supply, sewer line

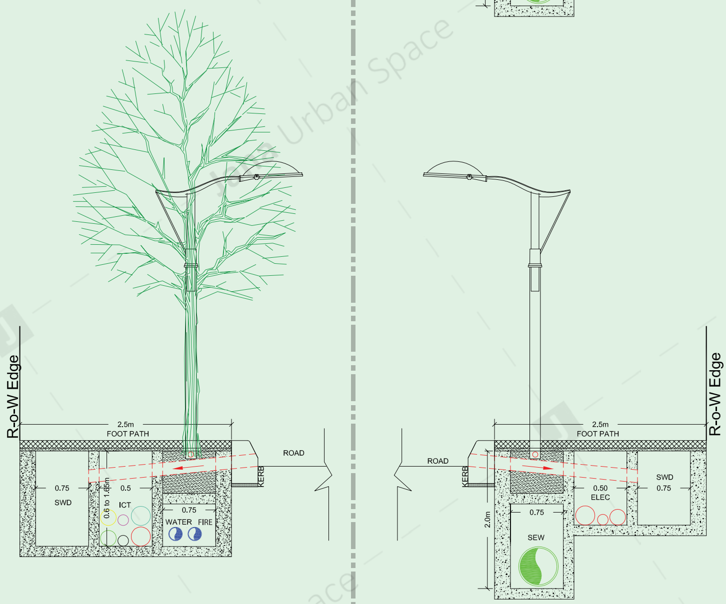
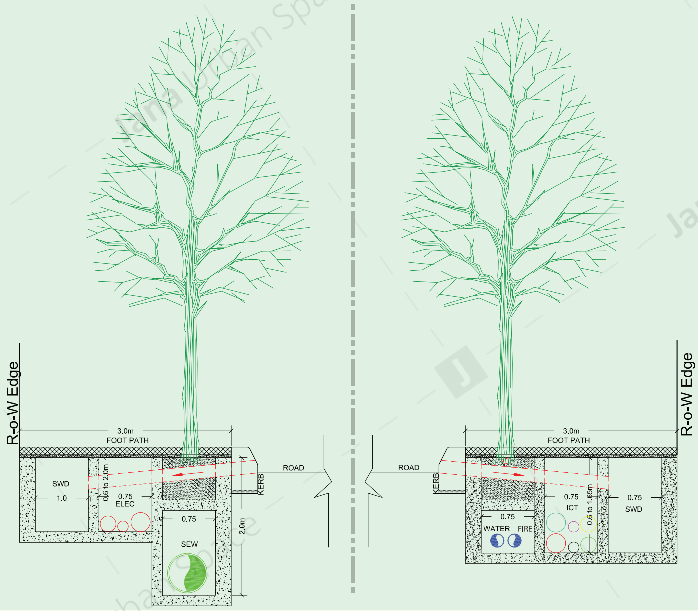
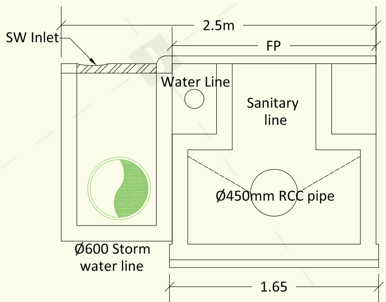


Image 2.80 >>
3m wide footpath
Utilities – SWD, Power line,
OFC, local water supply, sewer line





Special scenario: Water Line and Sewer mains on same side.In such cases, precautions need to be taken by constructing RCC separator walls

Finland, London, Amsterdam have shown progressive leadership in addressing the issues of networked infrastructure for their cities by constructing an entire underground tunnel system for these networks below the road surface. Such a dedicated system of corridors beneath the R-o-W provides space for all utility networks and ease of maintenance for individual service providers of : water, sewage, electricity, storm water, ICT and gas. Depending on the site specifications and the need, such corridors can vary in dimension. Precast elements laid at a minimum depth of 1.2 m below the road surface are generally used. The corridors have a gallery arrangement where cables and pipelines are vertically stacked and mounted against the walls. Ducts are provided for individual plots as last-mile connectivity thereby dramatically reducing any need for digging up the road surface for new connections.

Image 2.81 >>
Underground utility access grills
New York

(Refer plate 33, Pg 172)

CHAPTER

3

R-o-W DESIGN STANDARDS

tender SURE

R-o-W DESIGN PLATES

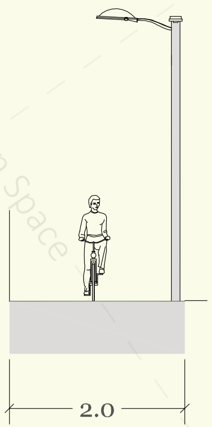
Table 3.1 >> R-o-W allocation for existing roads: *All dimensions are in meters*

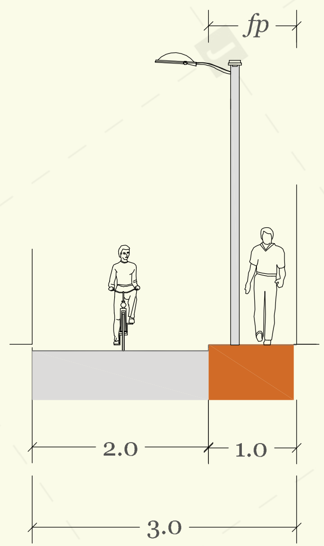
	Dwg Plate No	Road Type	R-o-W (M)	Travel Lane	Foot-path	Dedicated cycle lane	Parking lane	BRTS Lane
	1		2	2	---	---	---	---
T	2	Sub - Local	3	2	1	---	---	---
	3		5	3.5	1.5	---	---	---
	4		6	3	2+1	---	---	---
	5		7	4.5	1.5+1.0	---	---	---
	6		7	3.5	1.5+2.0	---	---	---
	7		8	5	1.5+1.5	---	---	---
	8		10	3+3	2+2	---	---	---
	9	Local	10	2.5+2.5	1.5+1.5	---	2	---
	10		12	4+4	2+2	---	---	---
T	11		12	3+3	2+2	---	2	---
	12		13	3.5+3.5	2+2	---	2	---
	13		13	2.5+2.5	2+2	---	2+2	---
	14		15	3.5+3.5	2+2	---	2+2	---
	15		15	2.5+2.5	2+2	1+1	2+2	---
	16		18	3+3	2+2	2+2	2+2	---
	17		18	5+5	2+2	2+2	---	---
	18	Collector	21	6+6	2+2	2	2	---
T	19		21	6+6	2+2	2+2	2 (Alt)	---
	20		28	6+6	2.5+2.5	2+2	2+2	---
T	21		30	5.5+5.5	3+3	2+2	---	3.5+3.5*
	22		33	6.5+6.5	3+3	2+2	---	3.5+3.5*
	23	Sub-arterial	34	7+7	3+3	2+2	---	3.5+3.5*
	24		39	10.5+10.5	2.5+2.5	2+2	---	3.5+3.5*
	25		40	10.5+10.5	3+3	2+2	---	3.5+3.5
	26		45	12+12	3+3	2+2	---	3.5+3.5
	27		46	12.5+12.5	2+2	2+2	2+2	3.5+3.5
	28		47	12.5+12.5	2.5+2.5	2+2	2+2	3.5+3.5
T	29	Arterial	48	11+11	2.5+2.5	2.5+2.5	2+2	3.5+3.5
	30		48	12.5+12.5	3+3	2+2	2+2	3.5+3.5
	31		50	12.5+12.5	3+3	2+2	2+2	3.5+3.5
	32		50	12.5+12.5	3+3	---	2+2	3.5+3.5
	33		60	17.5+17.5	3+3	2+2	---	3.5+3.5
	34		80	21.5+21.5	3.5+3.5	2.5+2.5	2+2	3.5+3.5

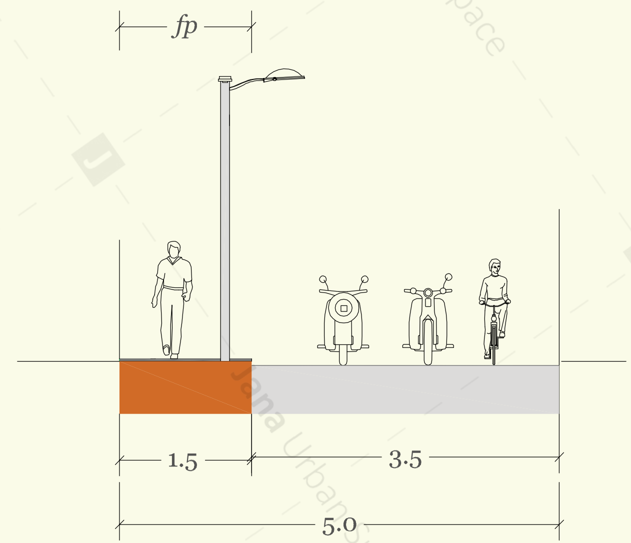
T: Typical R-o-W for new urban roads;
** BRT on Sub Arterial Road is an option that can also be utilized as a dedicated bus lane*
** Road widths mentioned above are excluding medians.*
** Travel lane includes Service lane.* ** Alt = Alternate Parking*

2m, 3m, 5m- Sub-local Roads

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



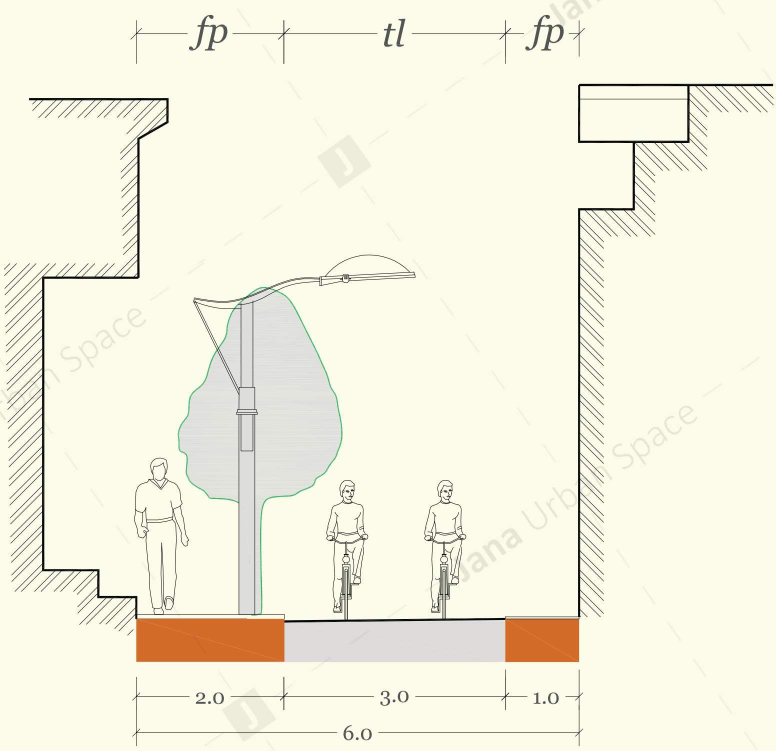




NOTE : 2 to 5 m wide R-o-W as per space availability, with shared access for pedestrian, bicycle. Motorised traffic access restricted to two and three wheeler vehicles.

6m LOCAL ROADS

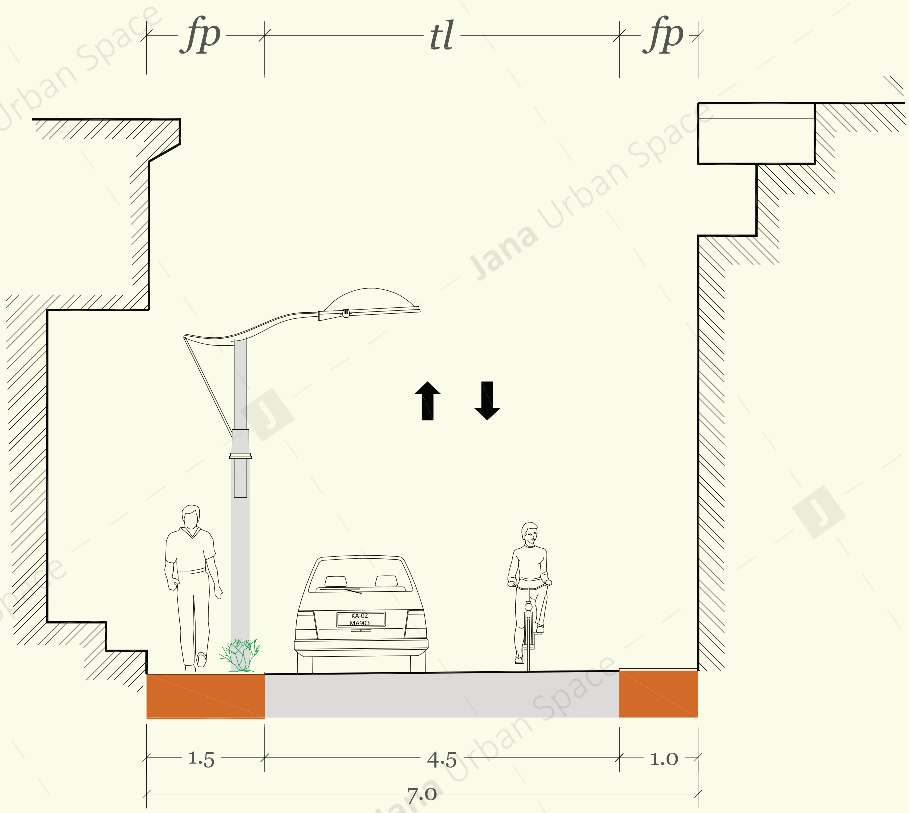
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



6.986 in

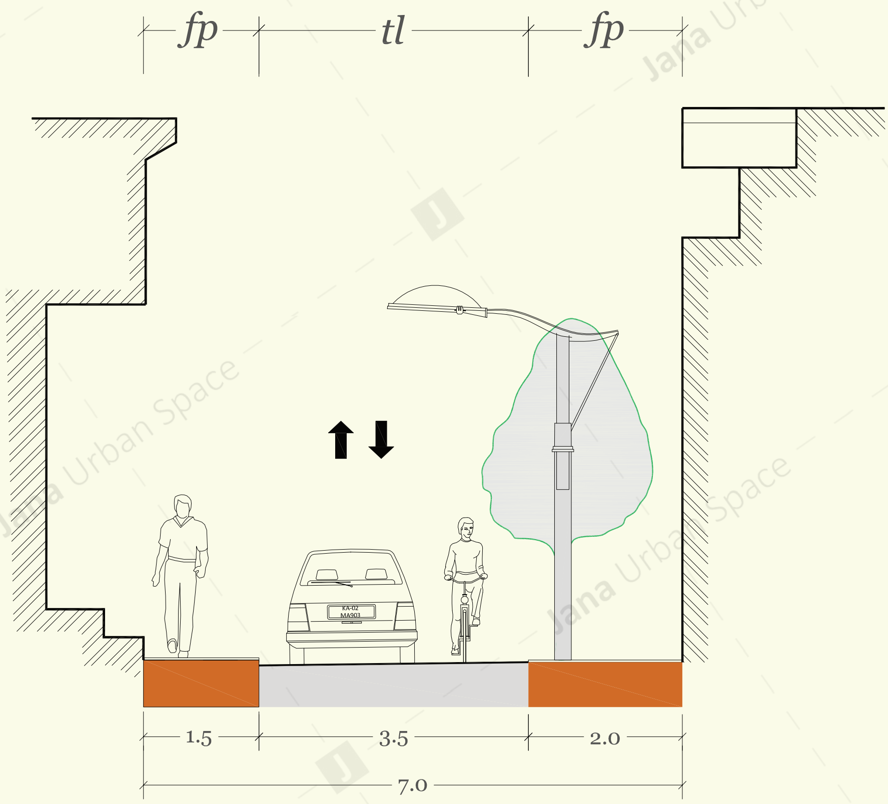
7m LOCAL ROADS

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



7A m LOCAL ROADS

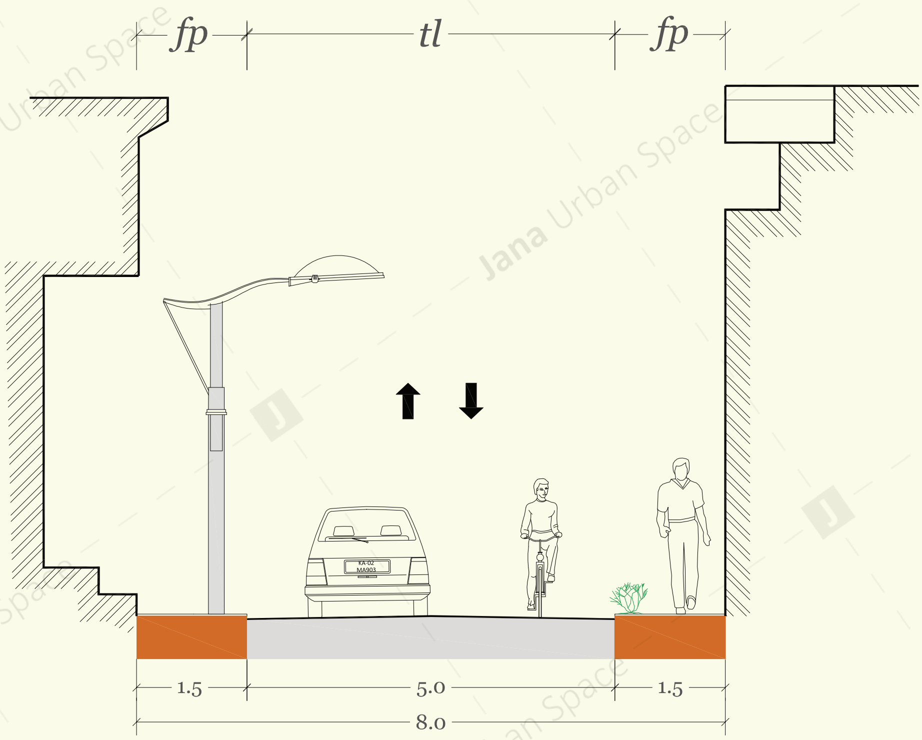
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



8 m LOCAL ROADS

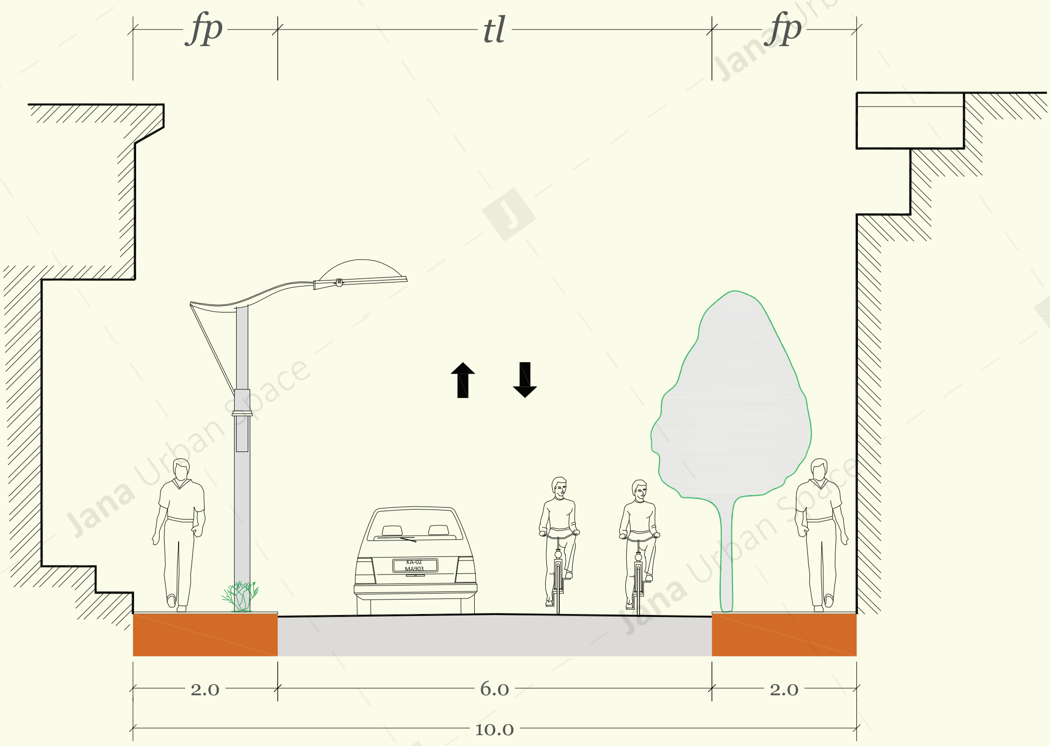
R-o-W Design Standards

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



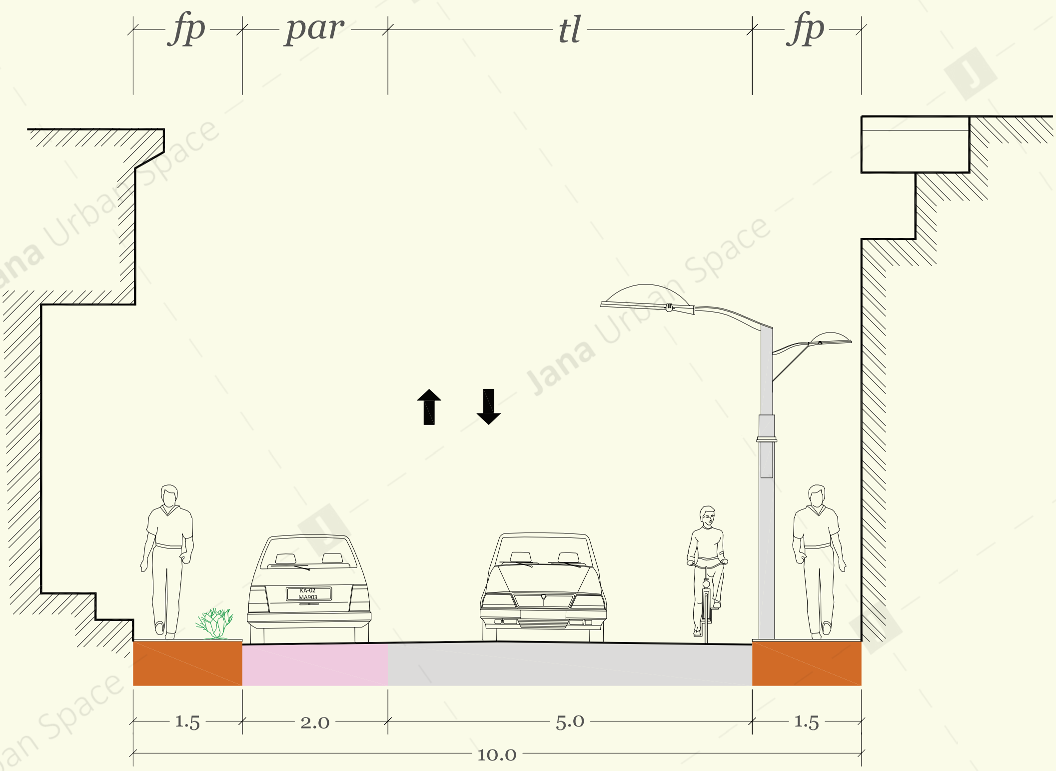
10m Local road without parking (typical)

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



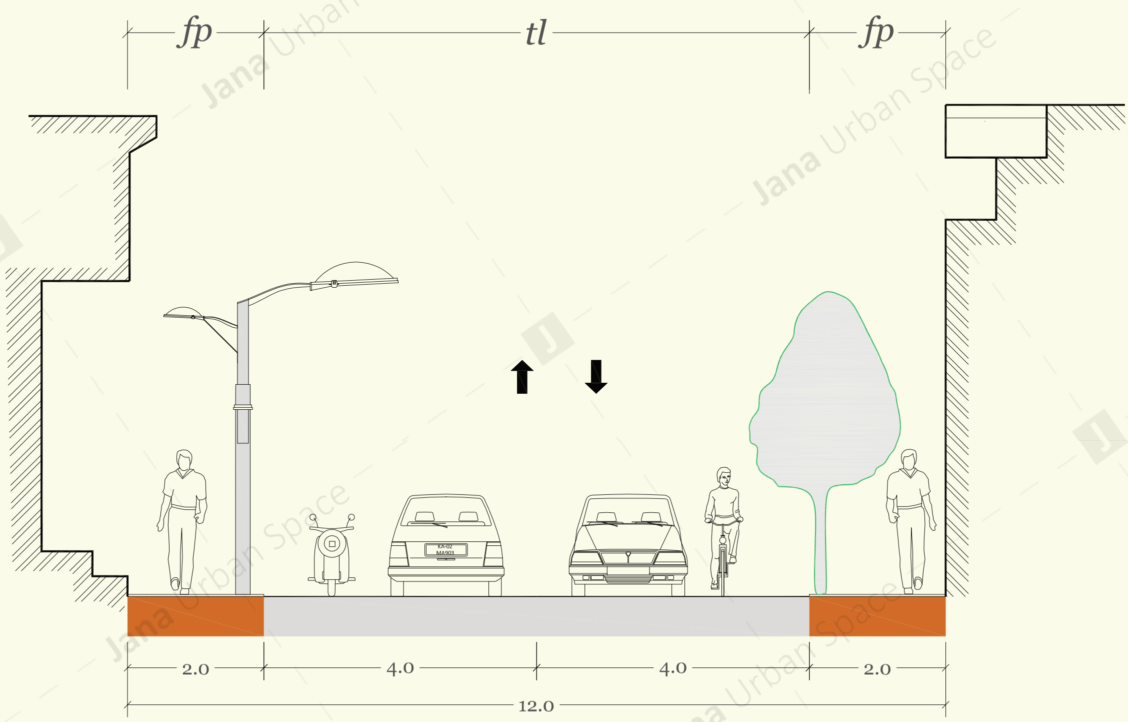
10A m Local road with parking

Footpath
Cycle lane
Parking
Travel lane
BRTS/LRTS
Landscape



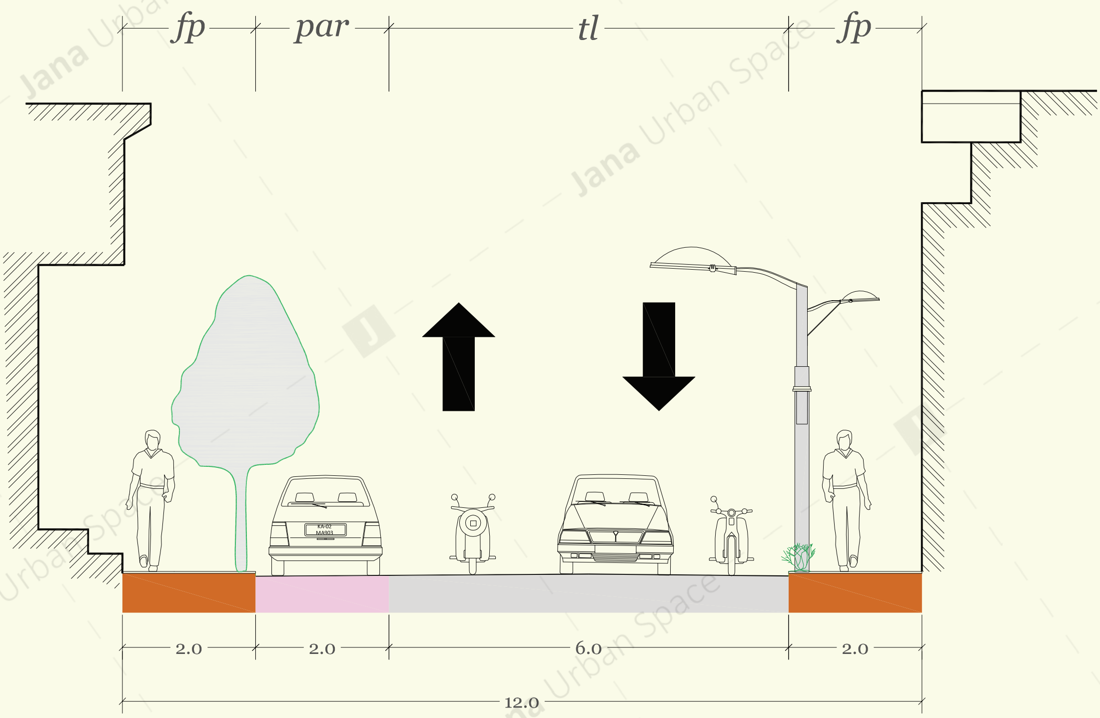
12 m Local road

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



12A m Local road

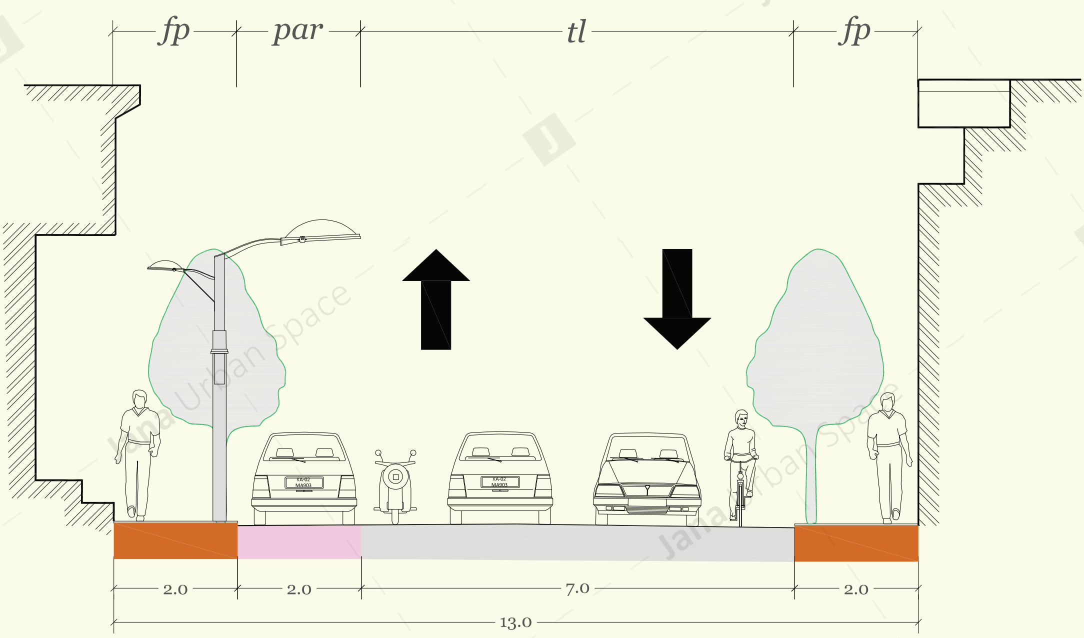
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



i. Travel lanes: 6m wide travel lanes for traffic flow.
ii. Pedestrians: 2m wide footpath on either side with a cross fall of 2.5%.
iii. Cyclists: travel lanes may be used by cyclists as well, with adequate traffic calming measures for safty
iv. Parking: 2-wheeler and parallel car parking on one travel lane as desirable
v. Landscaping: Any extra RoW width to be utilized for upgrading the experience of the road with appropriate hardscape and landscape.

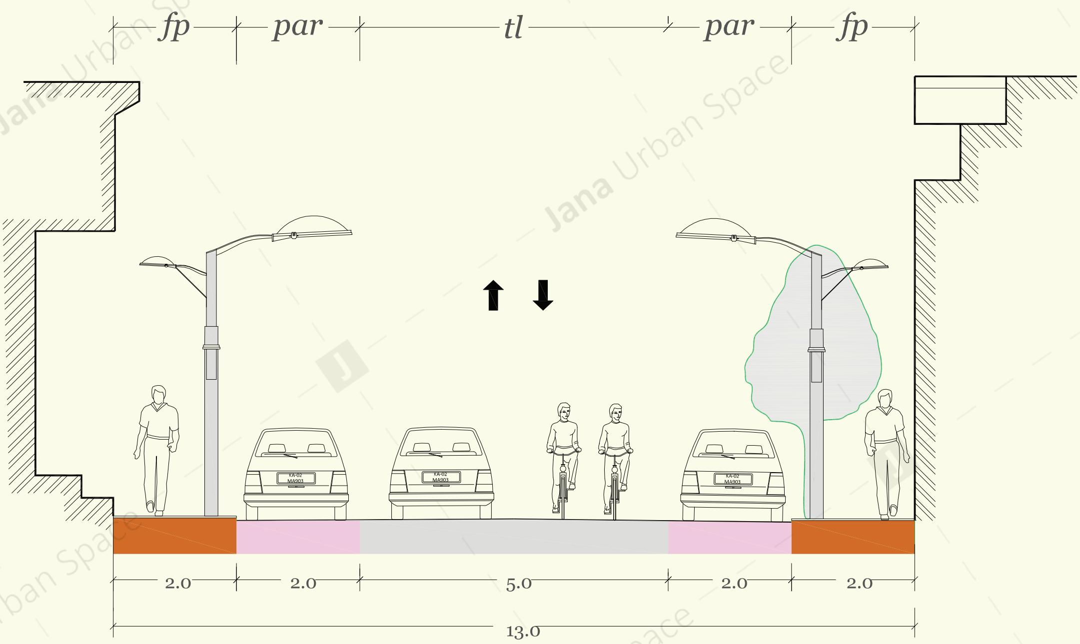
13 m Local road

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



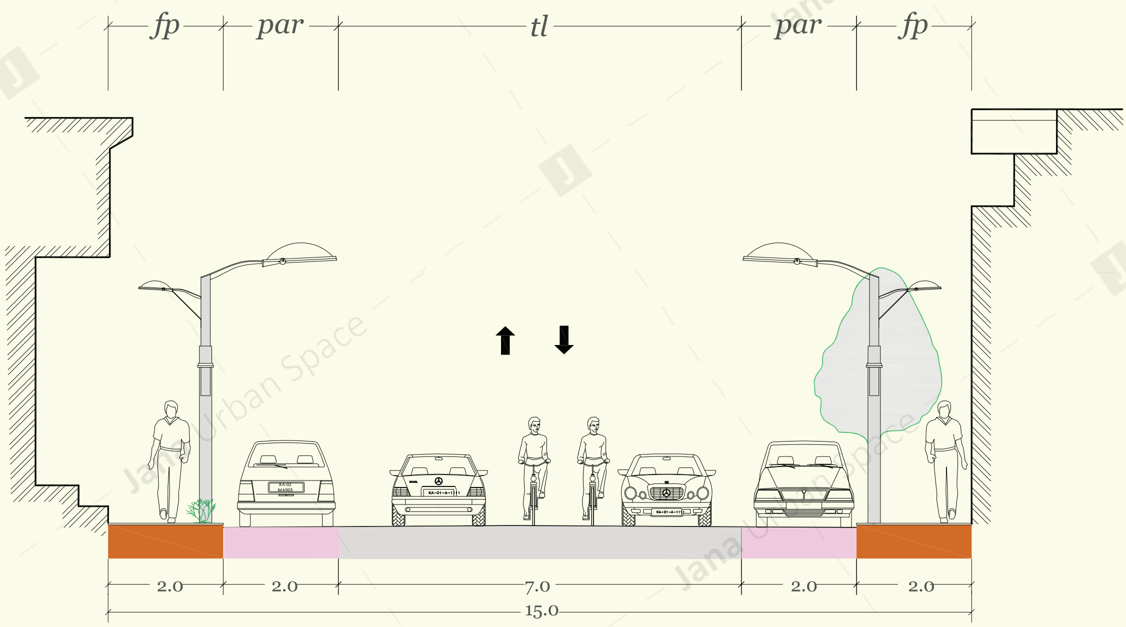
13A m Local road

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



15 m Local road

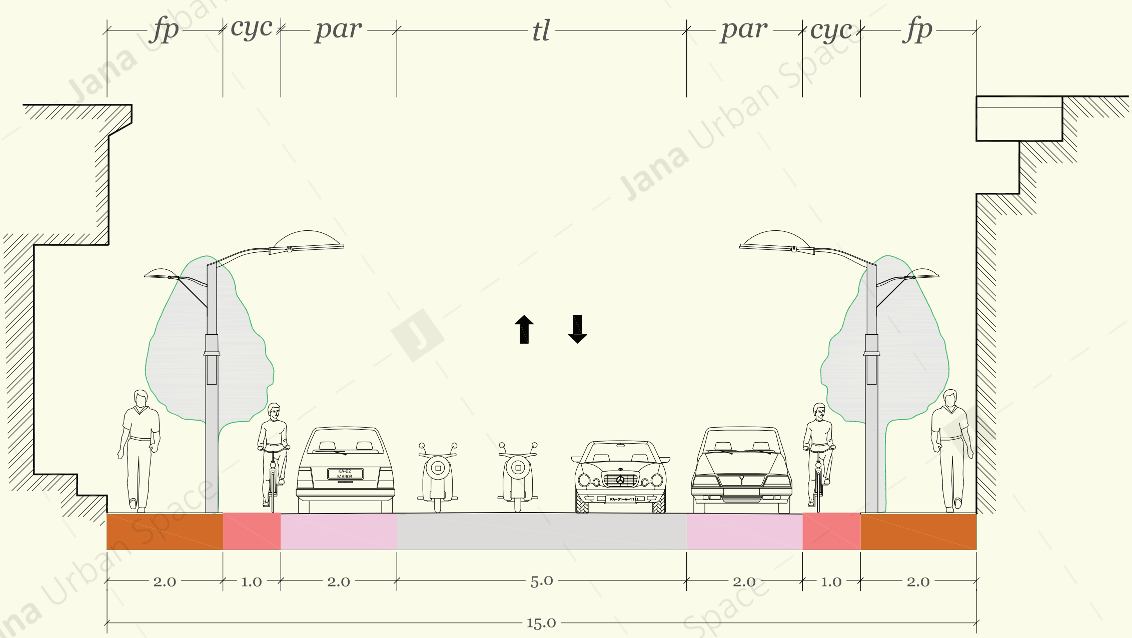
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



15 m Collector

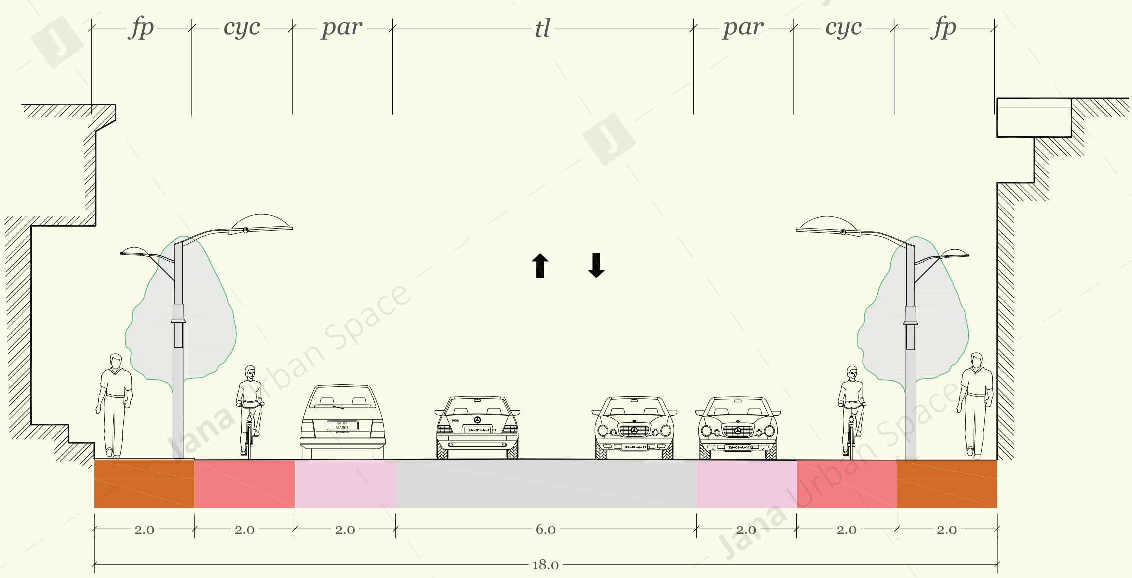
R-o-W Design Standards

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



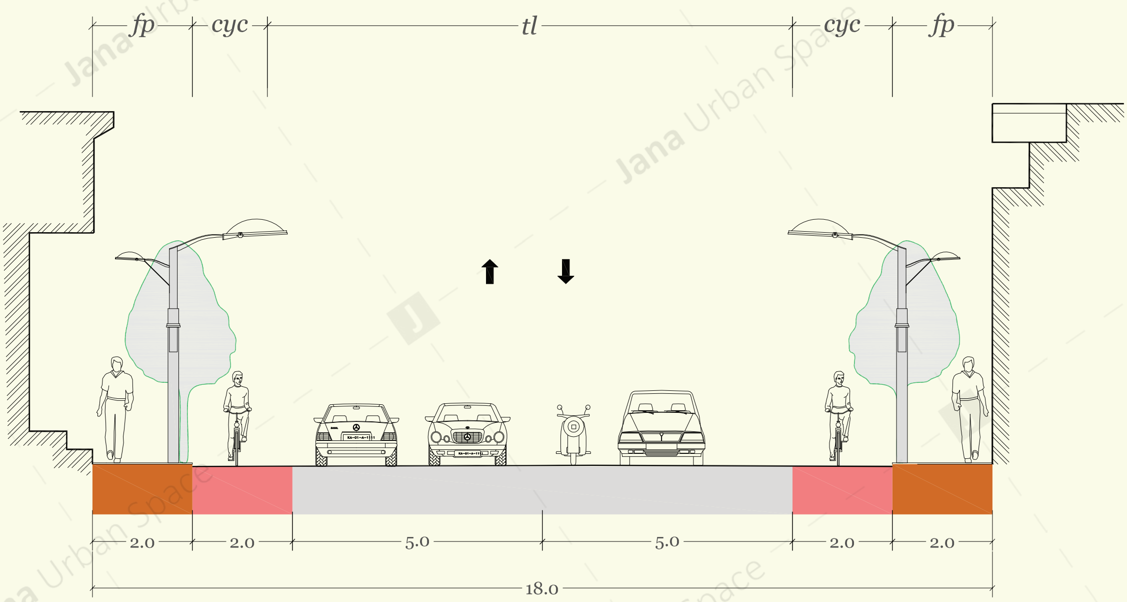
18 m Collector

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



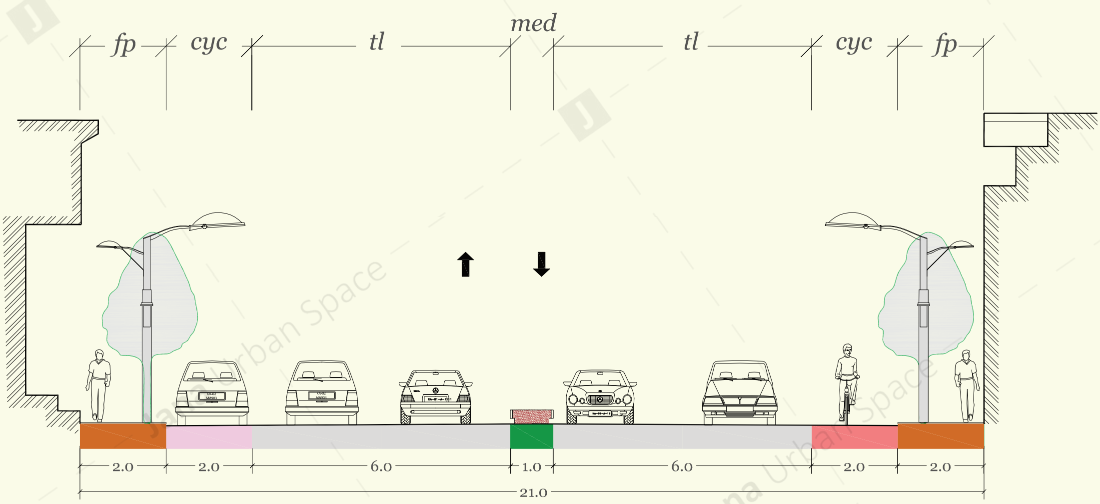
18A m Collector

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



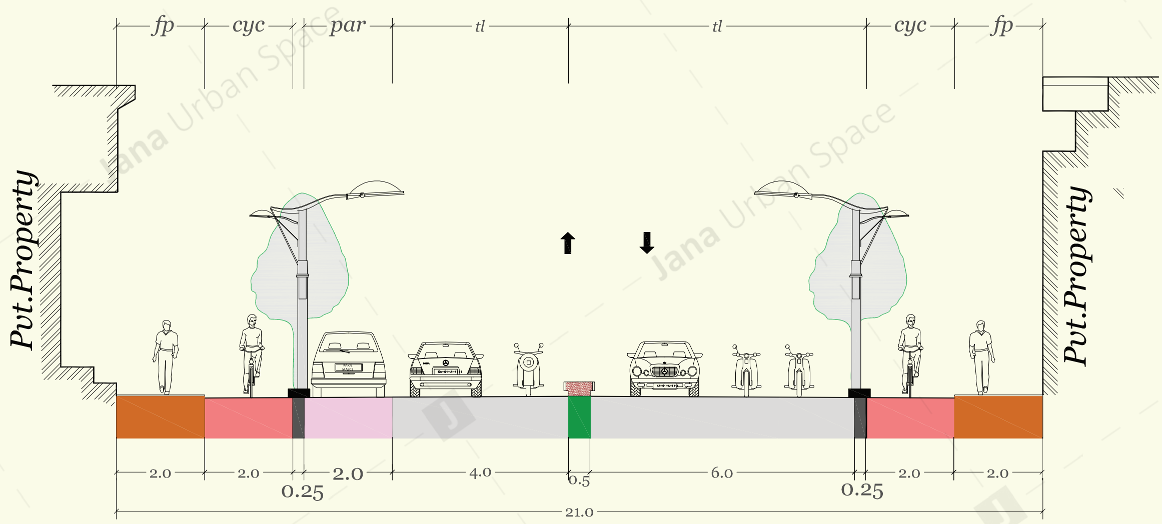
21 m Collector

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



21 m Collector

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape

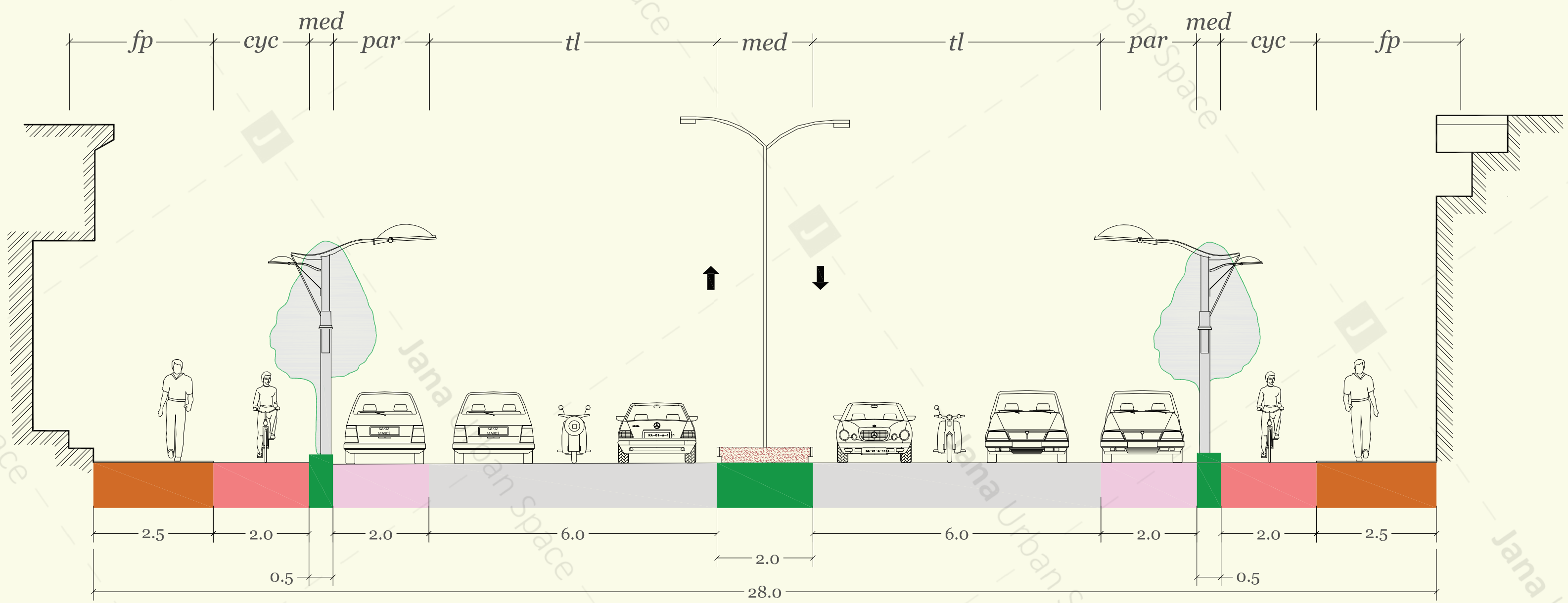


i. Travel lanes: 12m wide travel lanes
ii. Public Transport: local and feeder bus service
iii. Parking: restricted timing, alternate side parallel parking
iv. Pedestrians: 2m wide footpath on either side with a cross fall of 2.5%, pedestrian crossing at every 250m-300m distance.
v. Cyclists: 2m wide cycle track on either side, level with travel lanes. Median of 0.25m to divide travel lane and cycle tracks
vi. Landscaping: All extra RoW width to be utilized for upgrading the experience of the road with appropriate hardscape and landscape.

28m Collector Roads

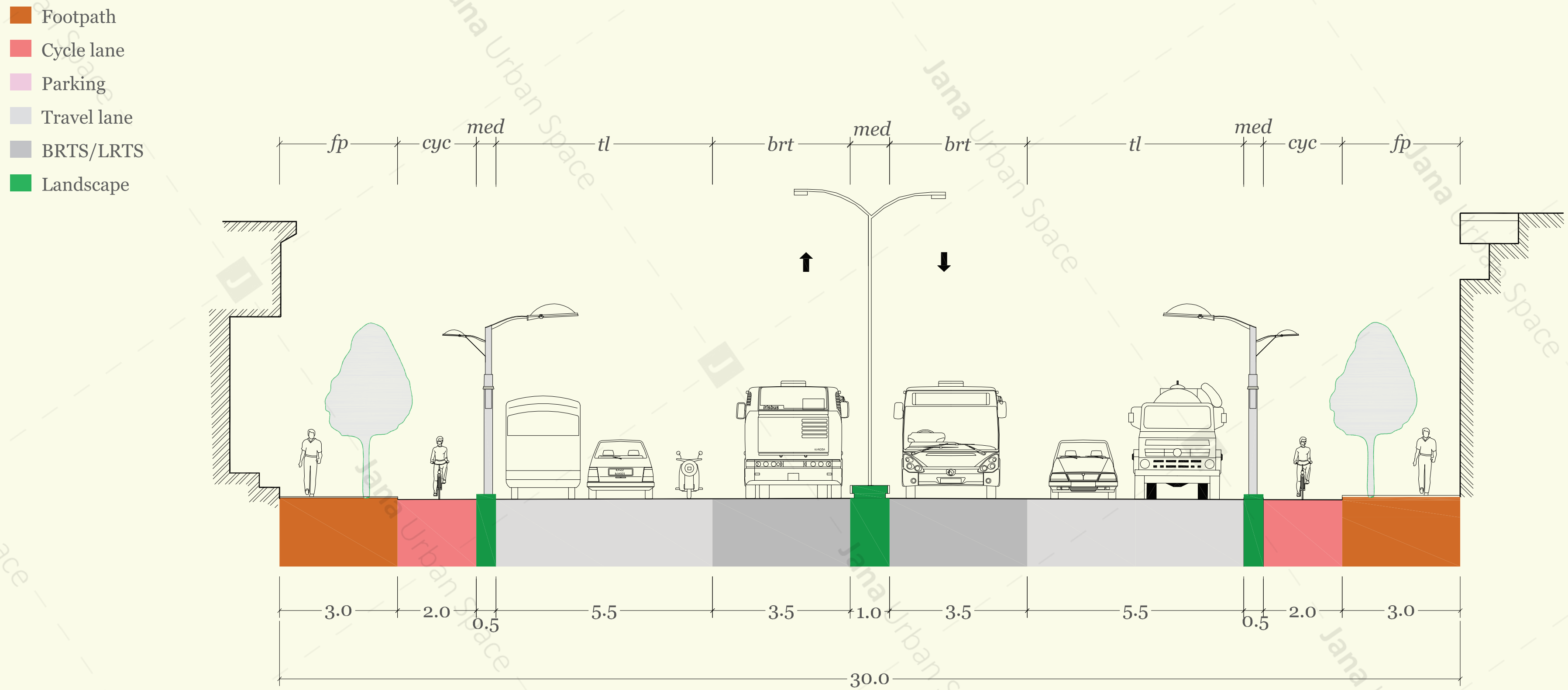
No 20

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



30m Sub-Arterial Roads(Typical)

No 21

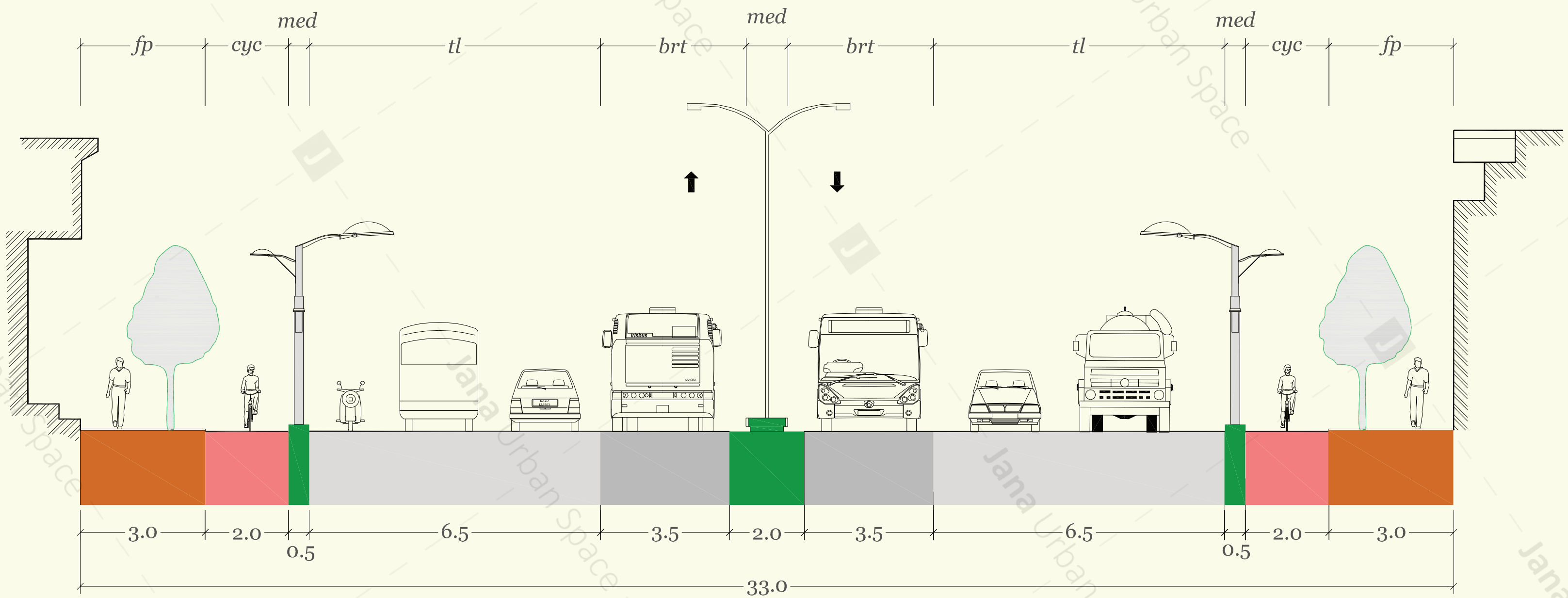


i. Travel lanes: 11m wide travel lanes for traffic flow and extreme ends for slow moving vehicles and buses.
ii. Public Transport: 8m wide space provided in the centre of R-o-W to accommodate BRT/LRT. Stops may be provided at every 1.5km -2km distance. Station width could range from 3m – 4m(refer BRT drawing sheet).
iii. Parking: On street parking to be avoided on high traffic sub-arterial roads
iv. Pedestrians: 3.0m wide footpath on either side with a cross fall of 2.5%. If the sub-arterial road is passing through dense urban settlements, pedestrian crossing to be provided at every 250m-300m distance. Underpass crossing with ramps is preferred, providing pedestrian comfort. In urban fringe where access is controlled, pedestrian crossing to be at 500m distance.
v. Cyclists: 2m wide cycle track, at level with travel lane,. Median of 0.5m to divide travel lane and cycle tracks.
vi. Landscaping: A utility strip of 0.5m-0.7m to house shrubs and street furniture. All extra RoW width to be utilized for upgrading the experience of the road with appropriate landscape

33m Sub-Arterial Roads

No 22

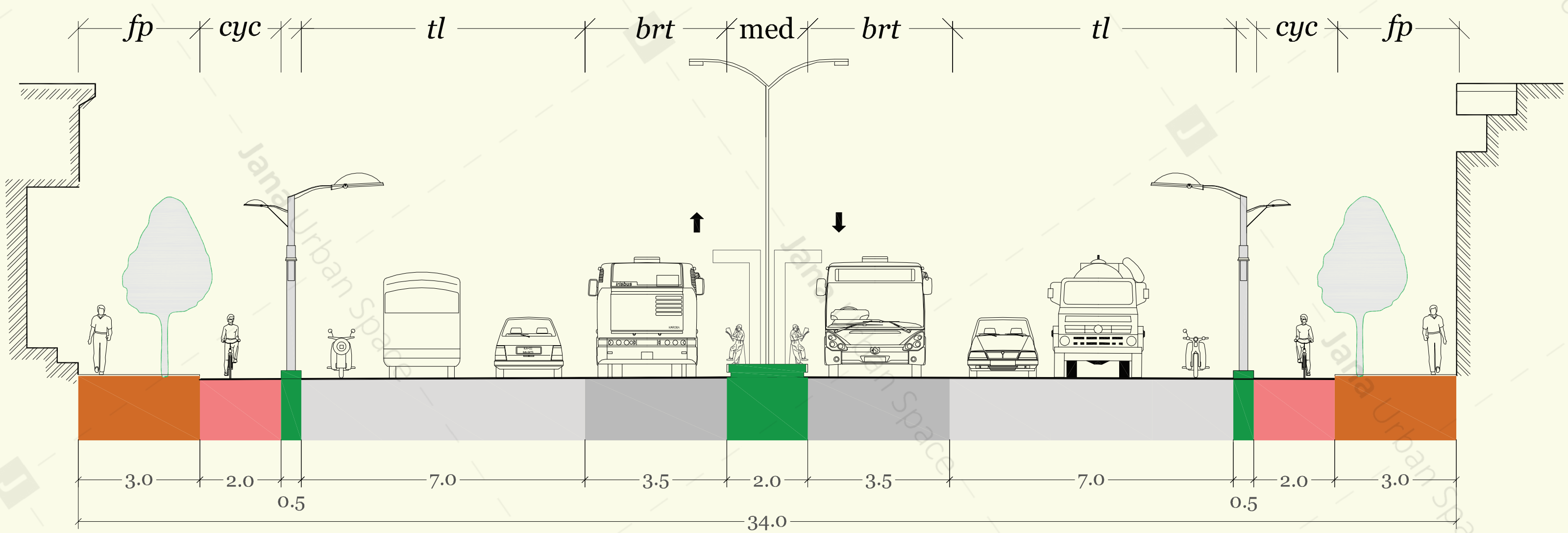
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



34m Sub-Arterial Roads

No 23

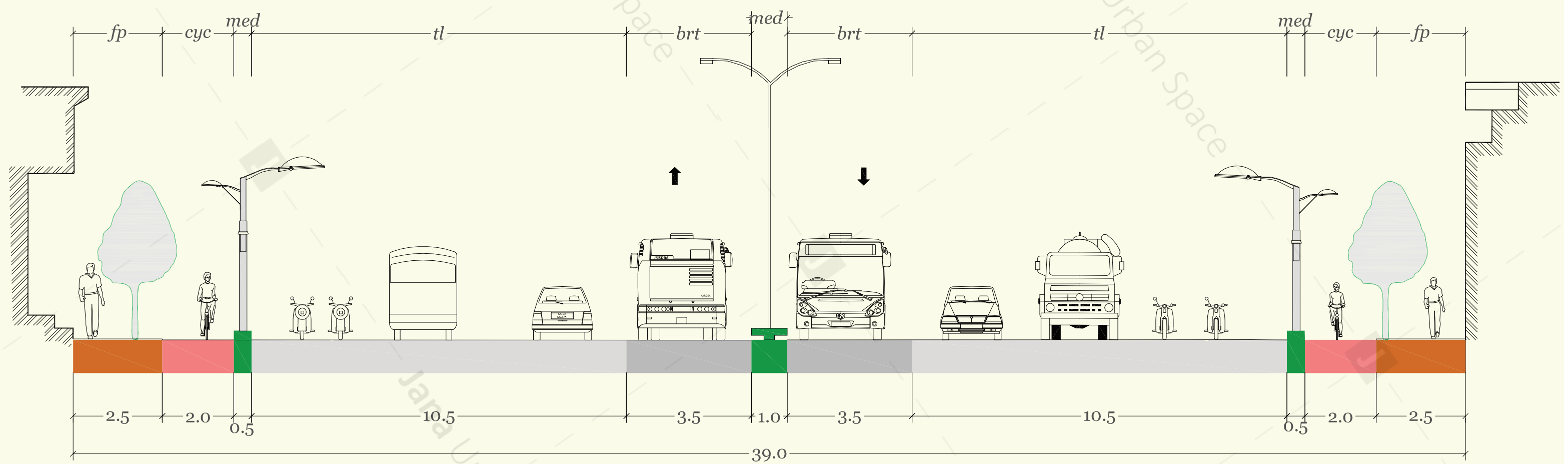
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



39m Arterial Roads

No 24

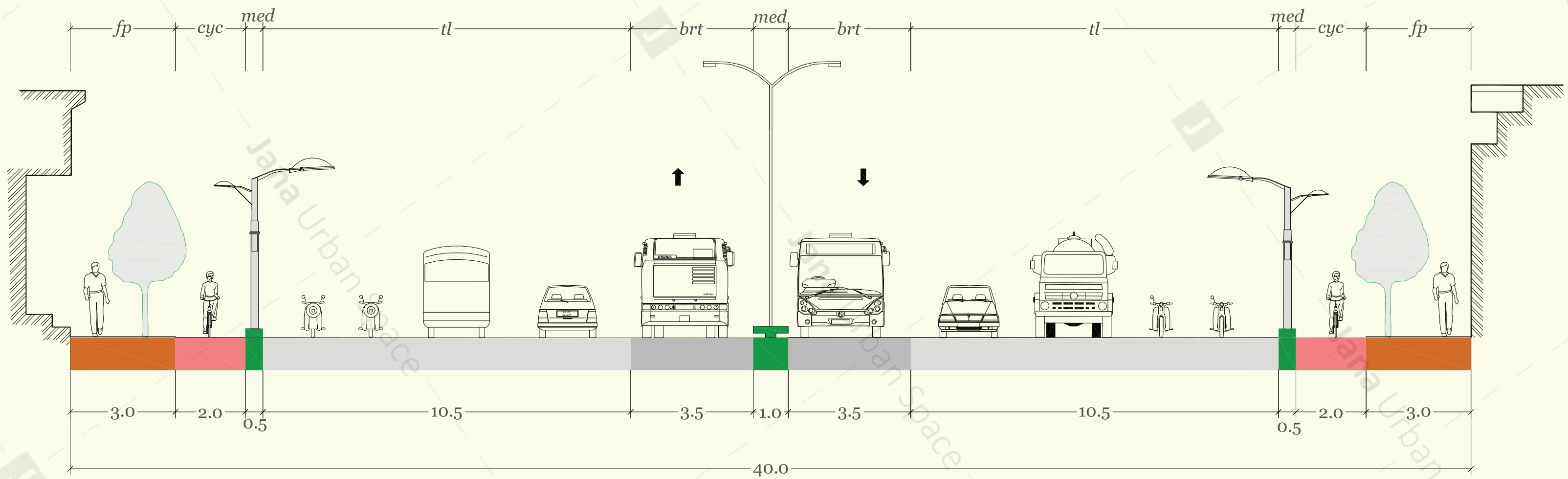
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



40m Arterial Roads

No 25

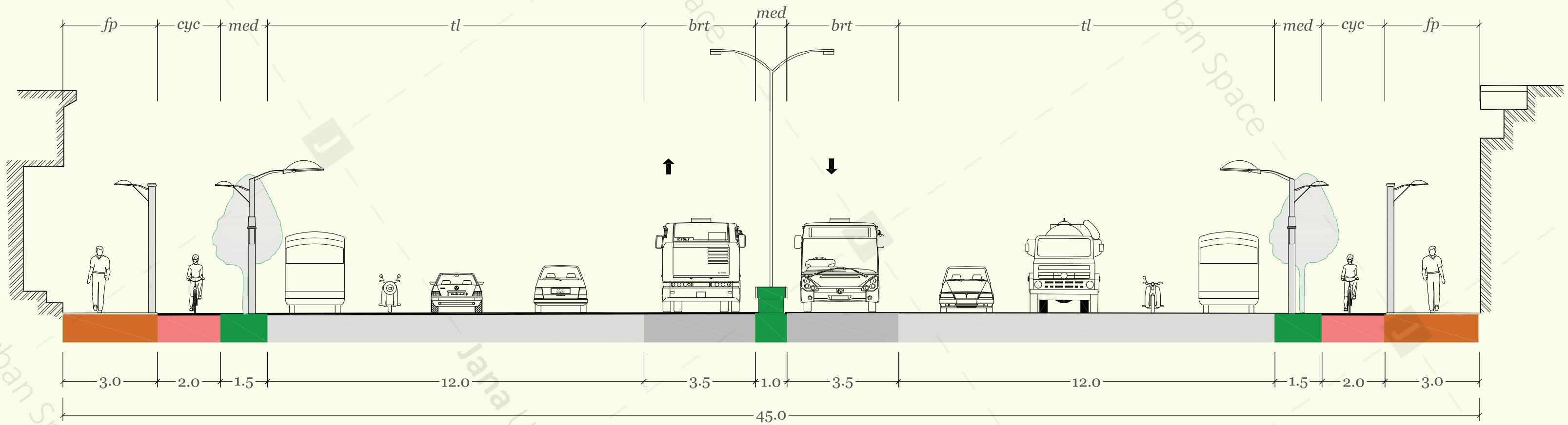
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



45m Arterial Roads

No 26

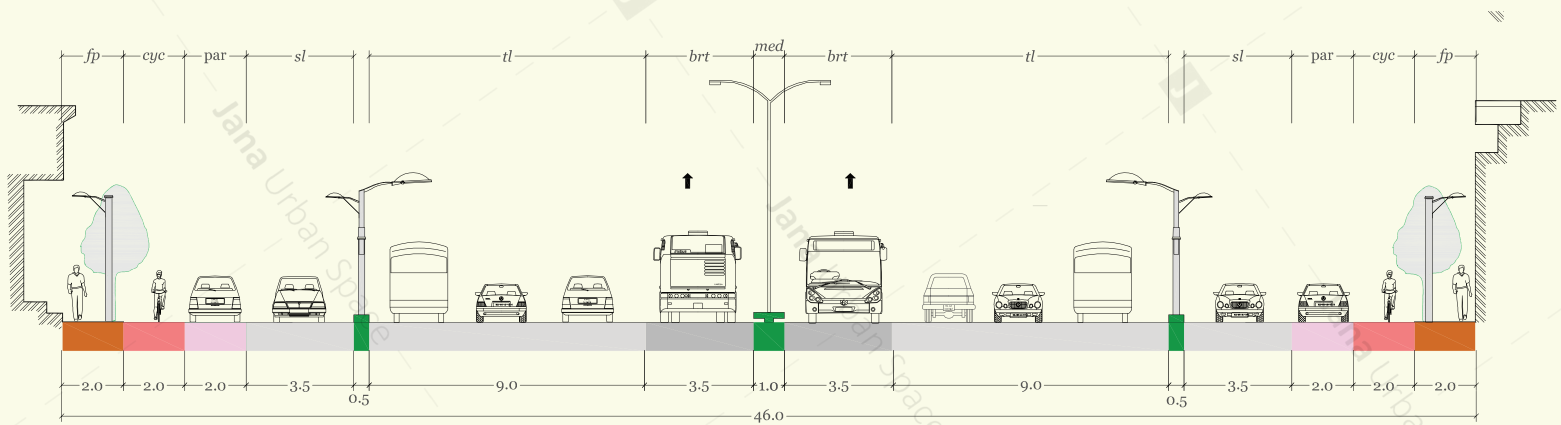
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



46m Arterial Roads

No 27

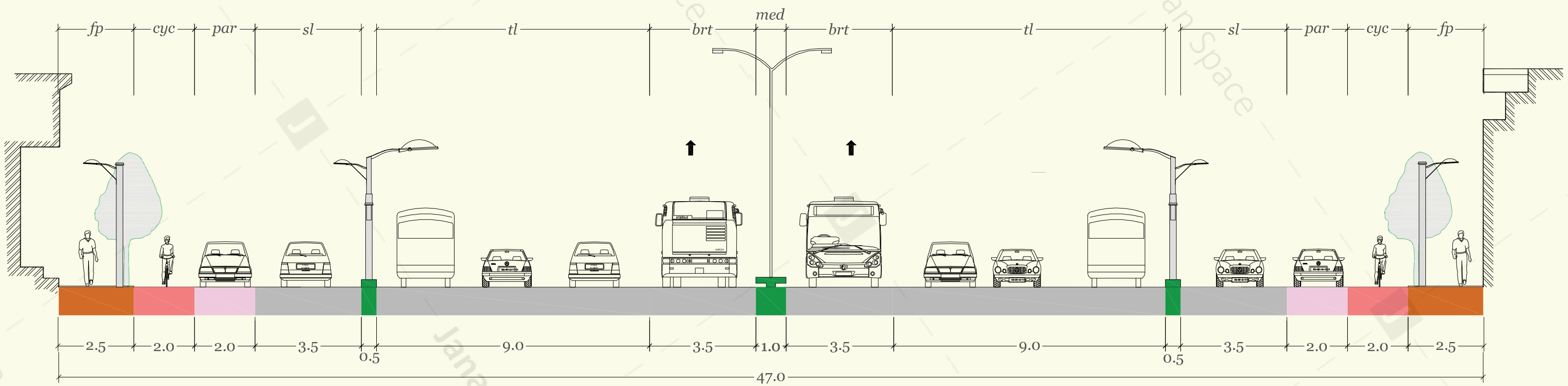
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



47m Arterial Roads

No 28

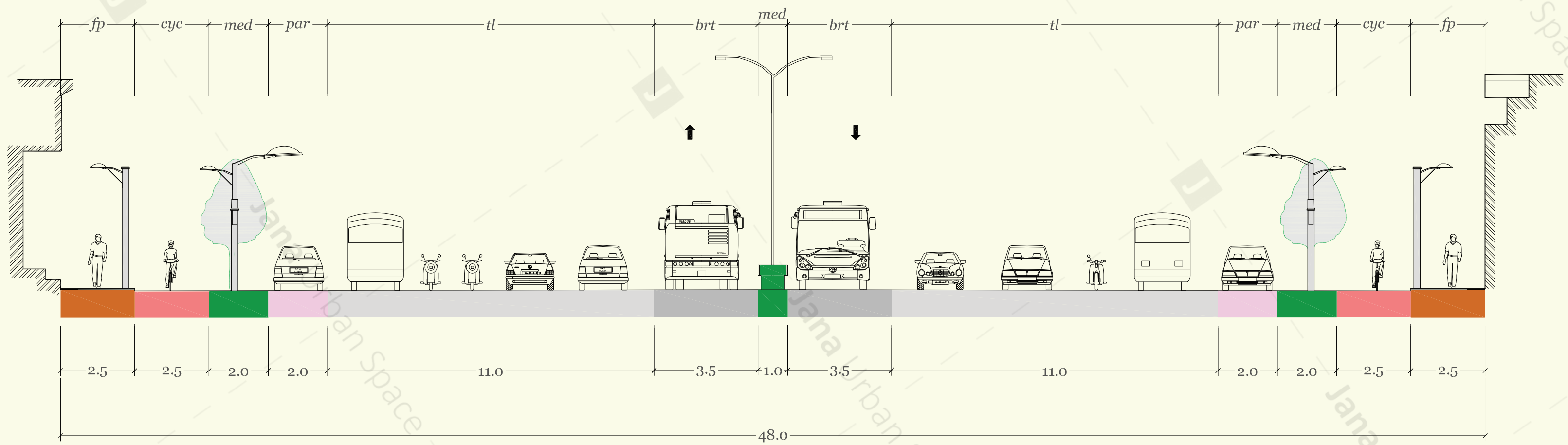
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



48m Arterial Roads with service lane (Typical)

No 29

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape

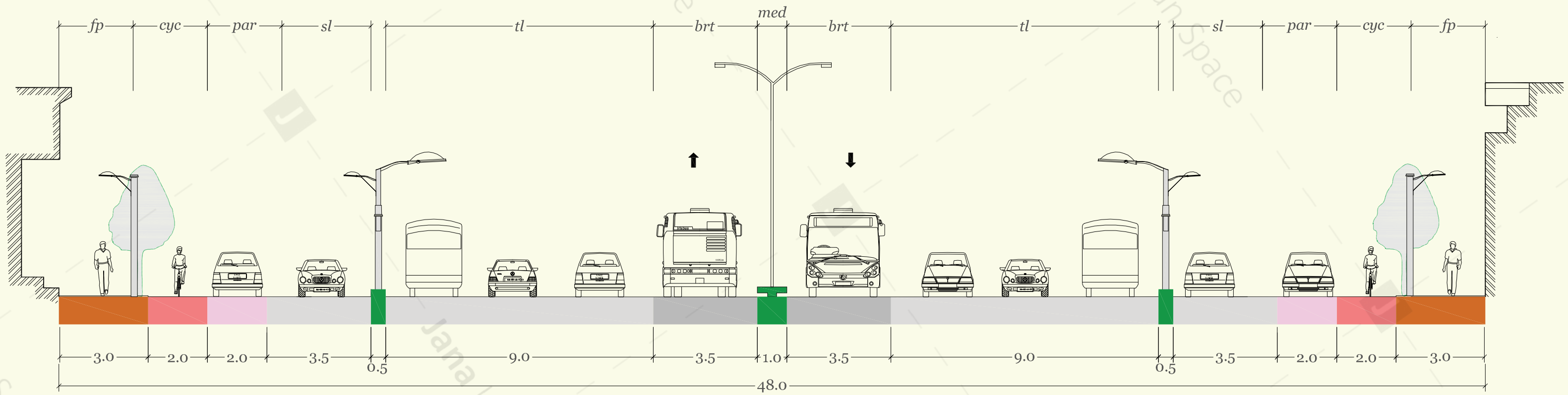


i. Travel lanes:22 m wide travel lanes with extreme ends for slow moving vehicles and buses. Service Roads of 11m provided on either ends for local traffic and access
ii. Public Transport: 8m wide space may be provided in the centre of R-o-W for future needs of mass rapid transport systems, like, Bus Rapid Transit, Metro Rail, Light Rapid Transit and dedicated bus lanes.
iii. Parking: Service roads may be utilized for parking if so desired as well as for repairs and emergency stops.
iv. Pedestrians: 2.5 m wide footpath on either side with a cross fall of 2.5%. If the arterial road is passing through dense urban settlements, pedestrian crossing to be provided at every 250m-300m distance. Underpass crossing with ramps is preferred, providing pedestrian comfort. In urban fringe where access is controlled, pedestrian crossing to be at 1000m distance.
v. Cyclists: 2.5m wide cycle track on either side.

48mA - Arterial Roads without service lane (Typical)

No 30

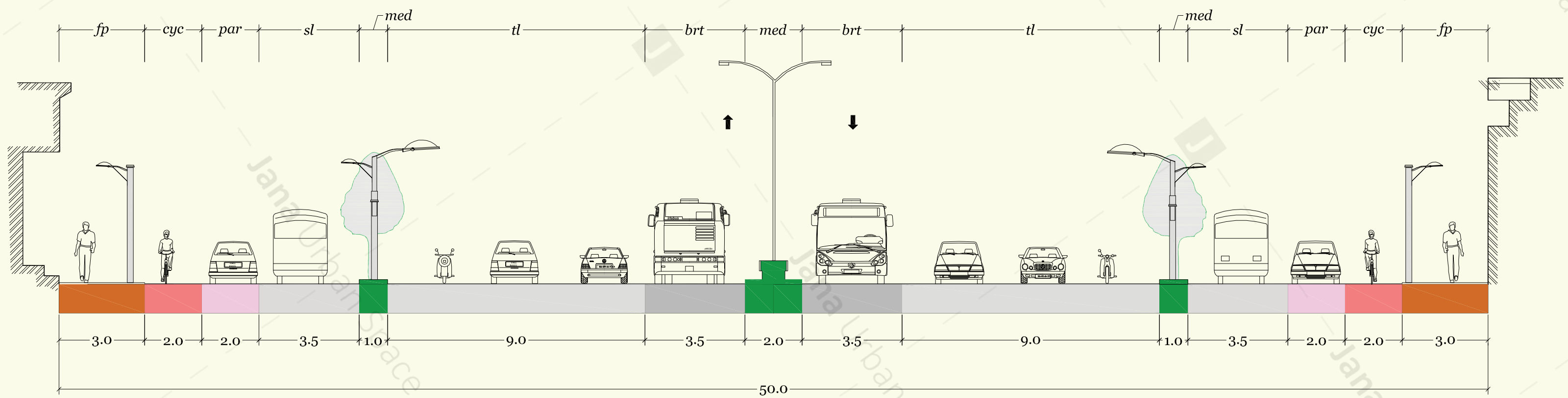
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



50mA - Arterial Roads

No 31

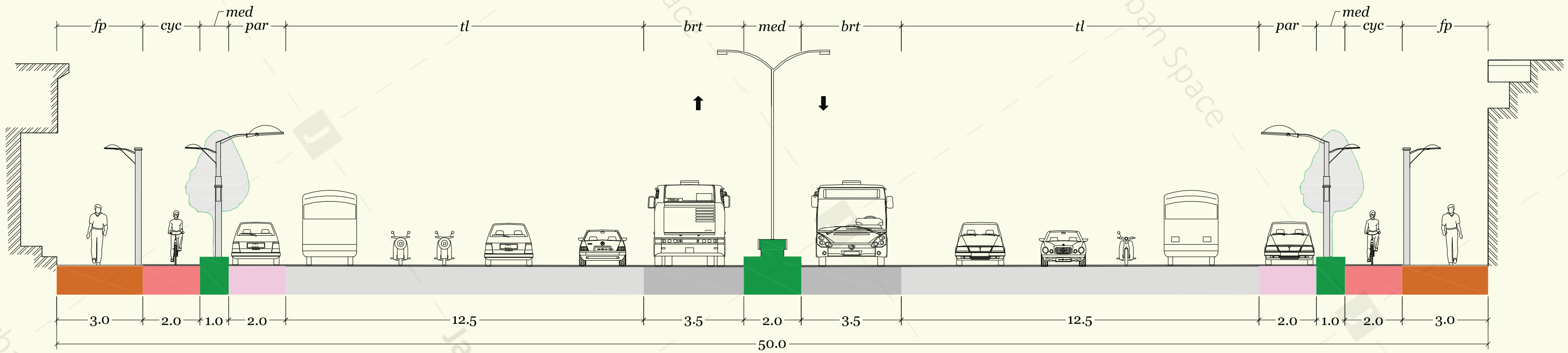
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



50m - Arterial Roads

No 32

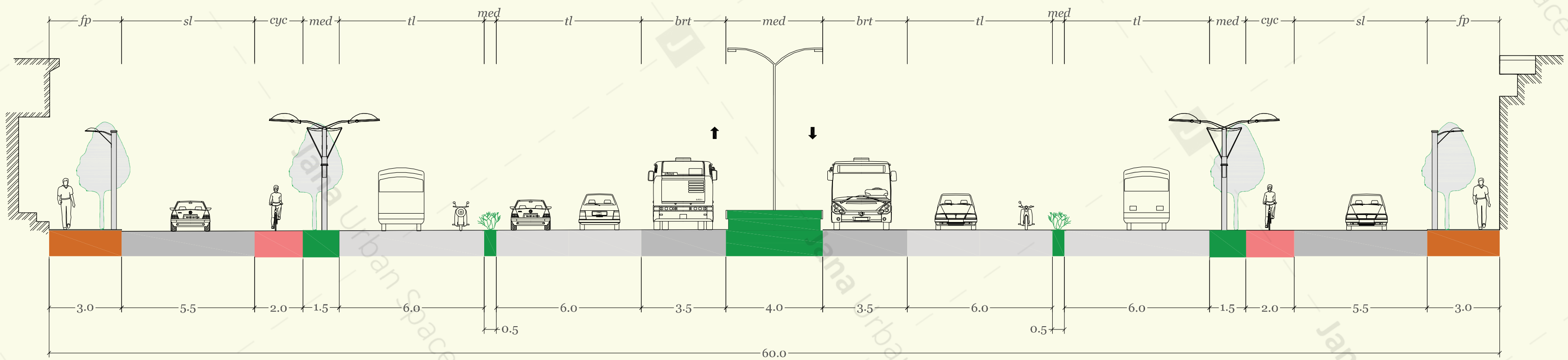
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



60m Arterial Roads

No 33

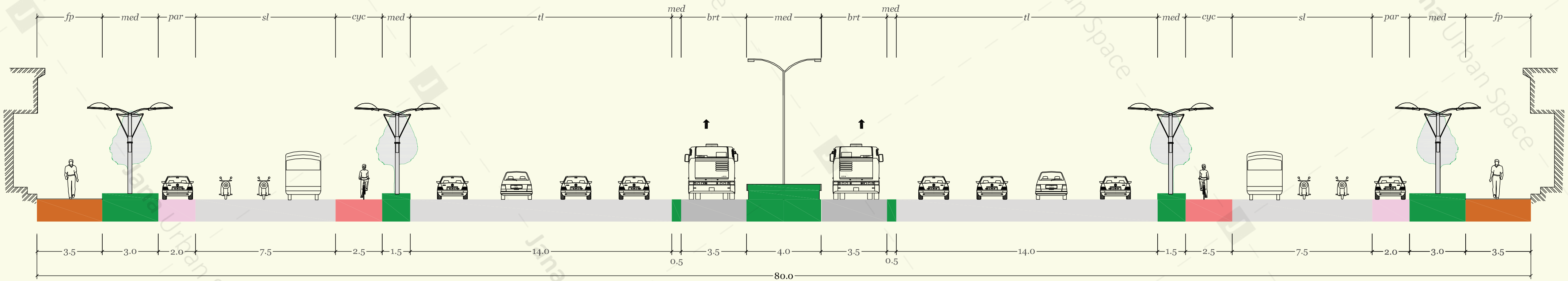
- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



80m Arterial Roads

No 34

- Footpath
- Cycle lane
- Parking
- Travel lane
- BRTS/LRTS
- Landscape



Traditional system of road drainages still serving the ancient city - Cusco, Peru

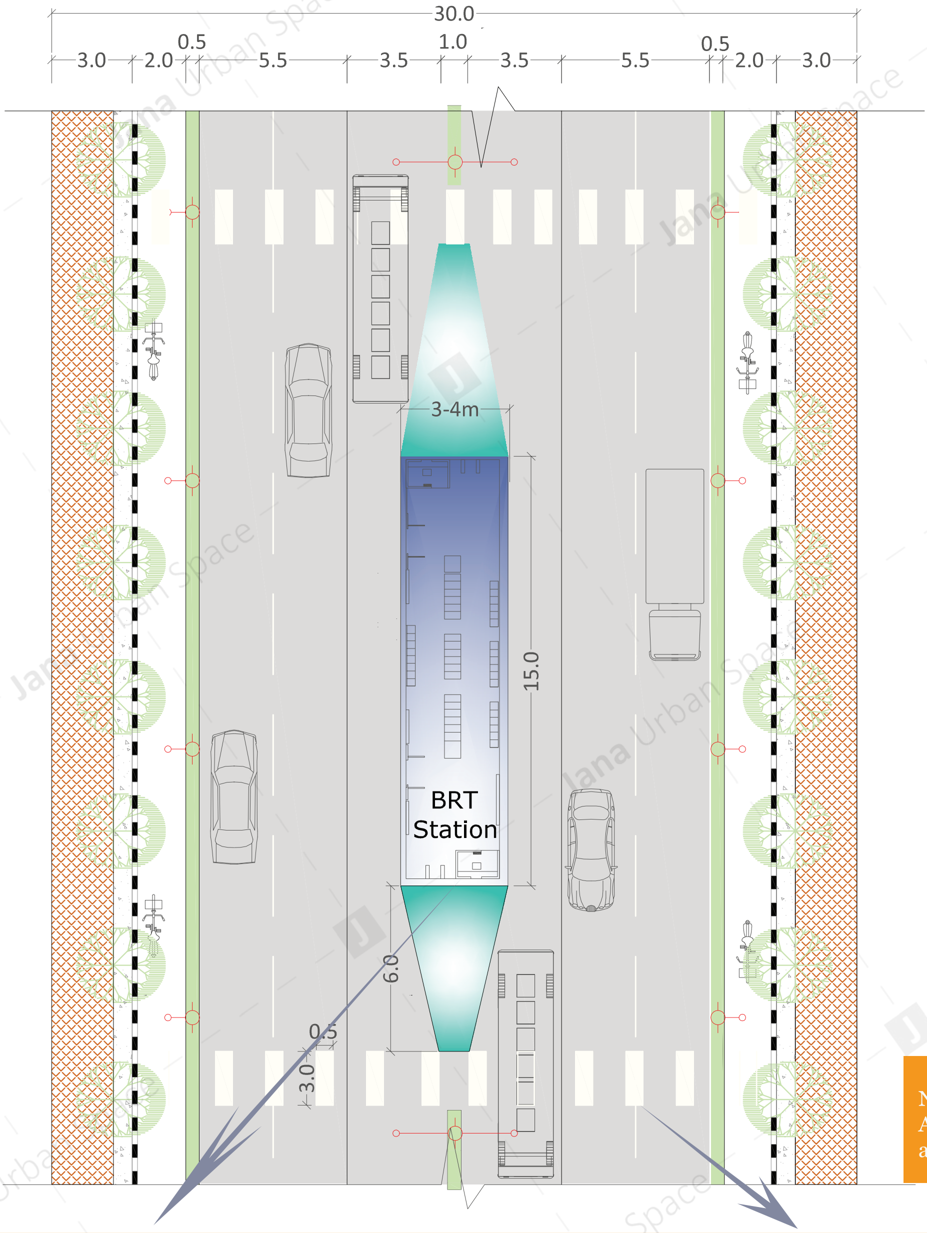
DESIGN DETAIL PLATES

PLATES

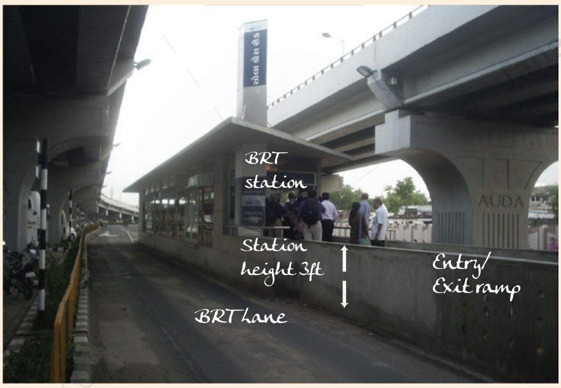
1 - BRTS STATION

Public Transport Facilities

Refer Section 2.2.2



Note :
All dimensions are in metres

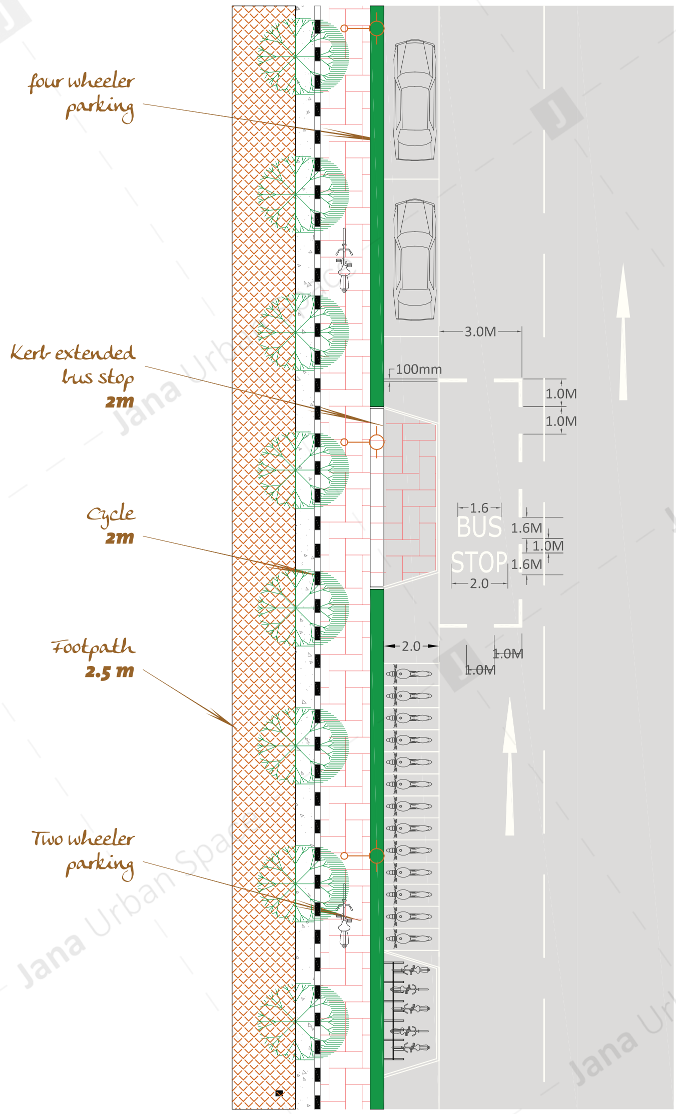


Ahmedabad BRT Station

Pedestrian Crossing at Ahmedabad BRT Station

2 - BUS STOP

Refer Section 2.2.2



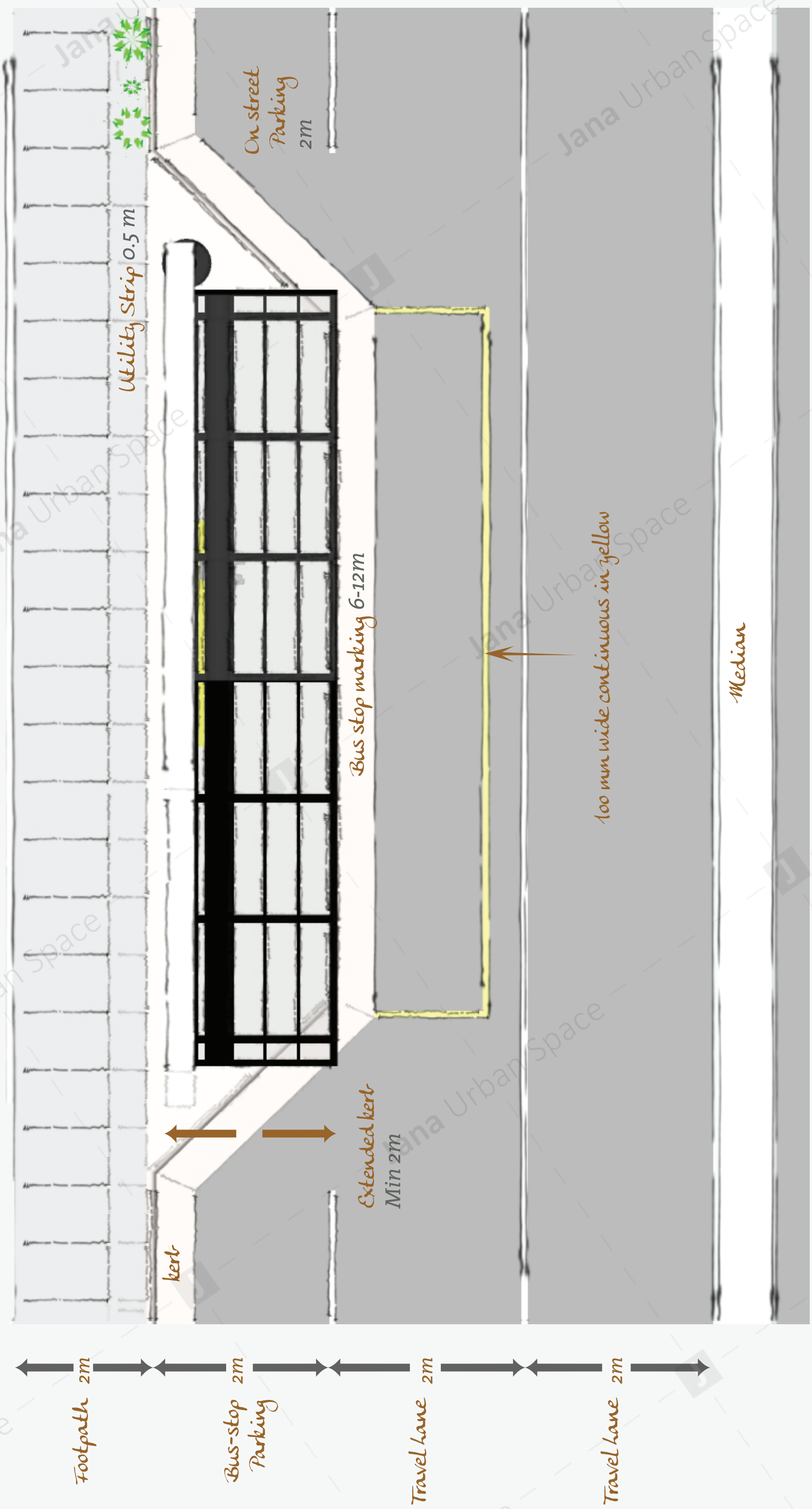
Note :
All dimensions are in metres

Bus Stop

3 - BUS STOP

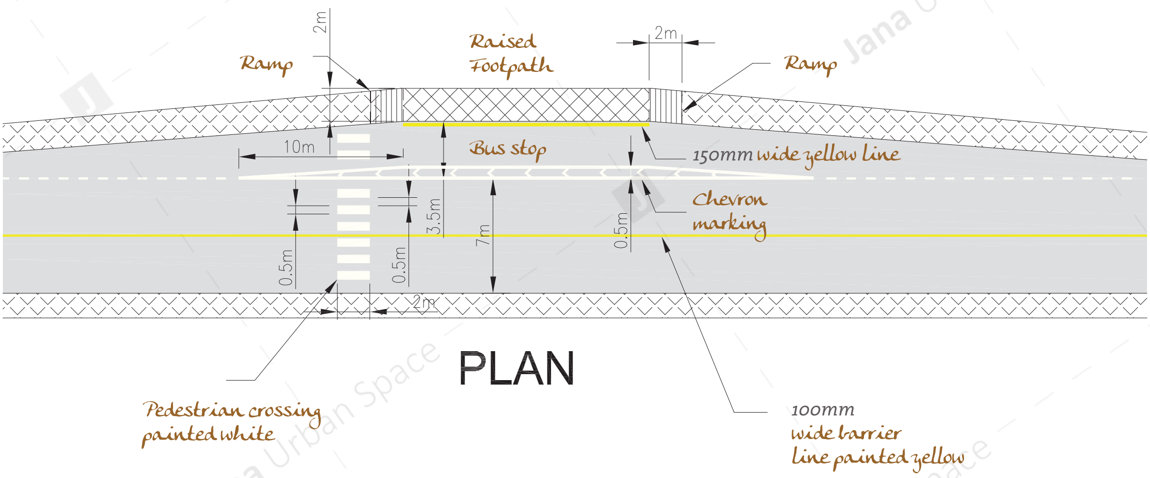
Public Transport Facilities

Refer Sectio 2.2.2



4 - BUS BAY DETAILS

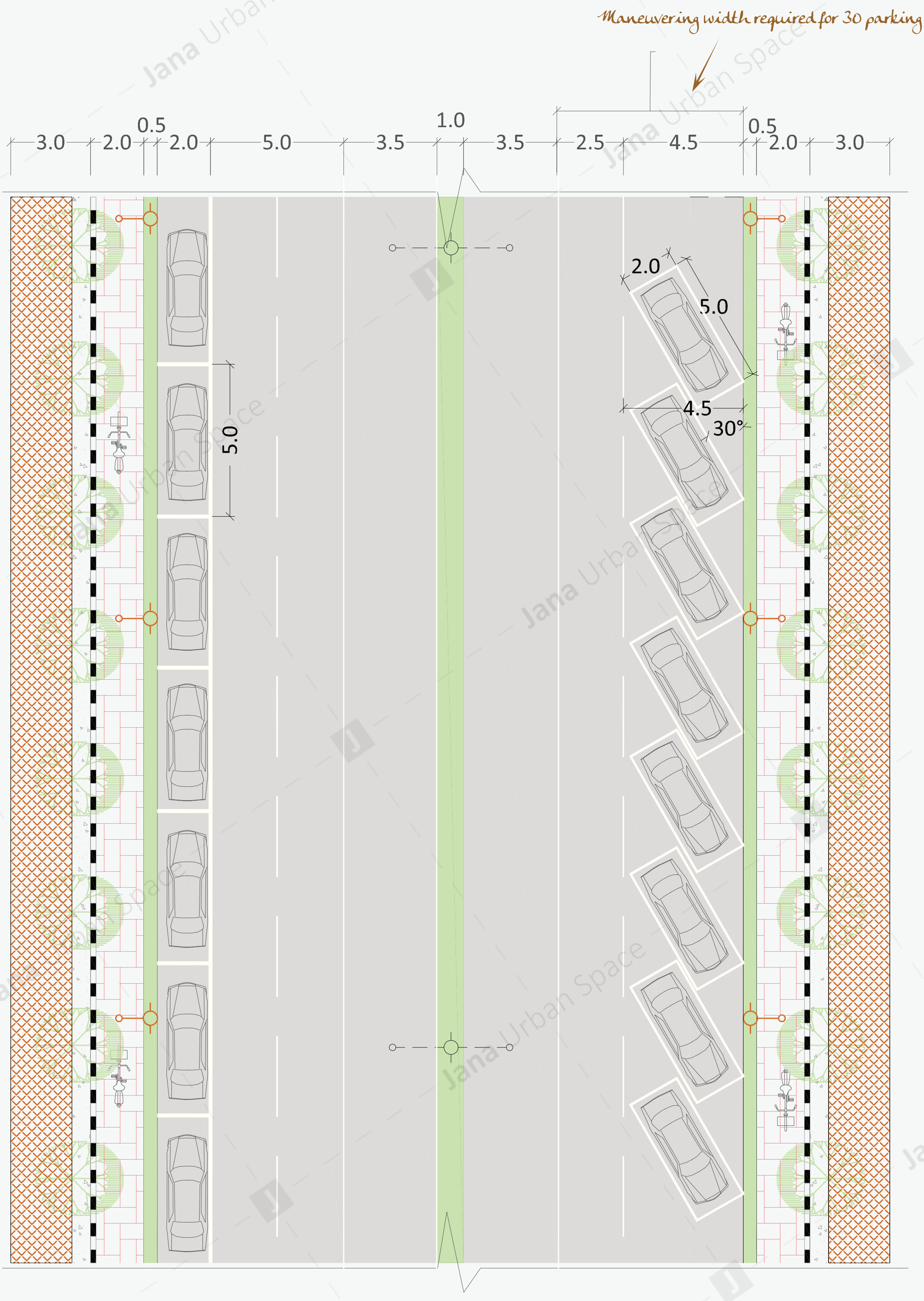
Refer Section 2.2.3



PLAN

5 - ON-STREET CAR PARKING

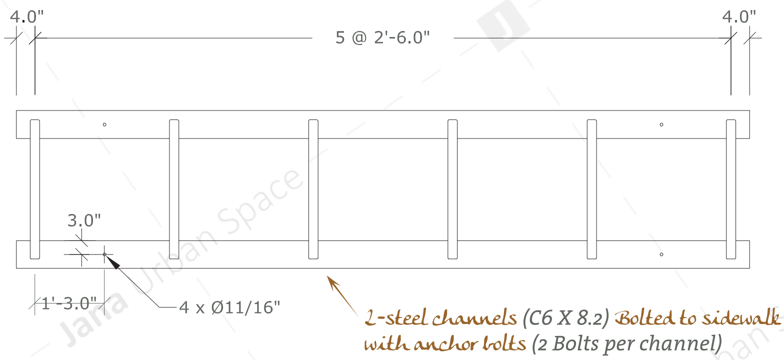
Refer Section 2.3



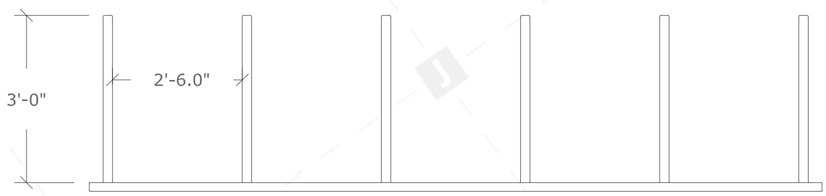
Note : All dimensions are in metres

6 - PARKING DETAILS - BICYCLE

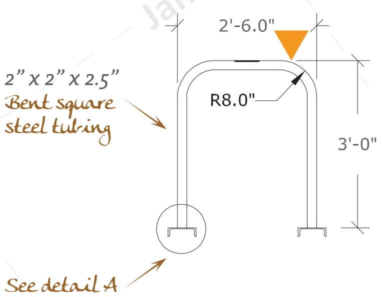
Refer Section 2.3



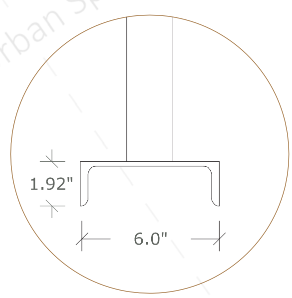
Plan View



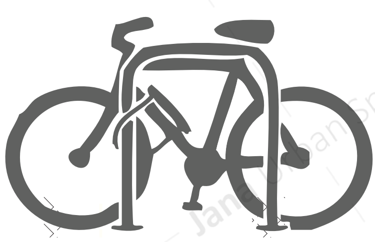
Front View



Side View

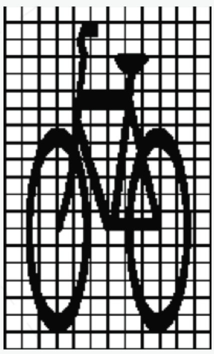


Detail A

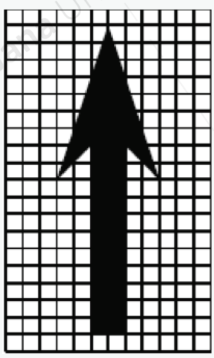


7 - PARKING DETAILS - BICYCLE

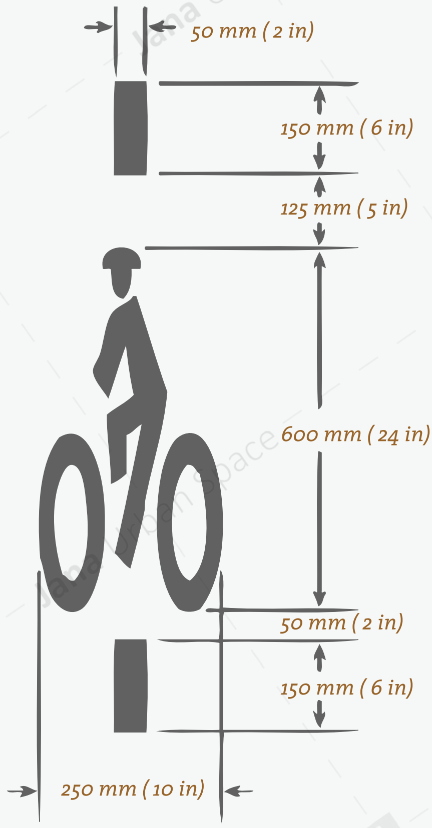
Refer Section 2.3 & 2.5.4



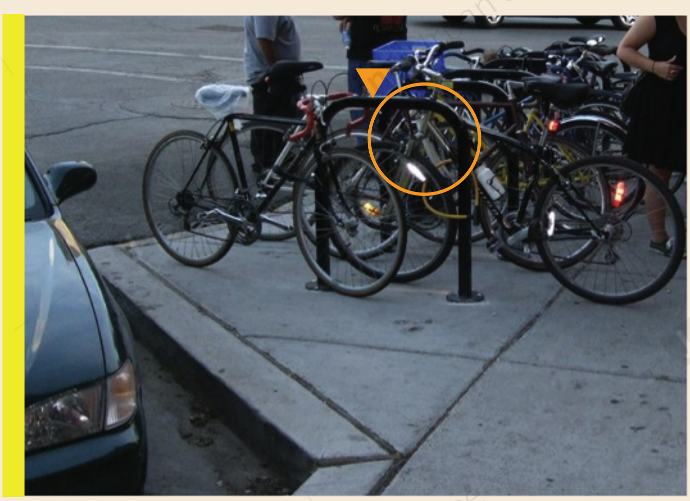
Bicylce Lane Symbol



Directional Arrow

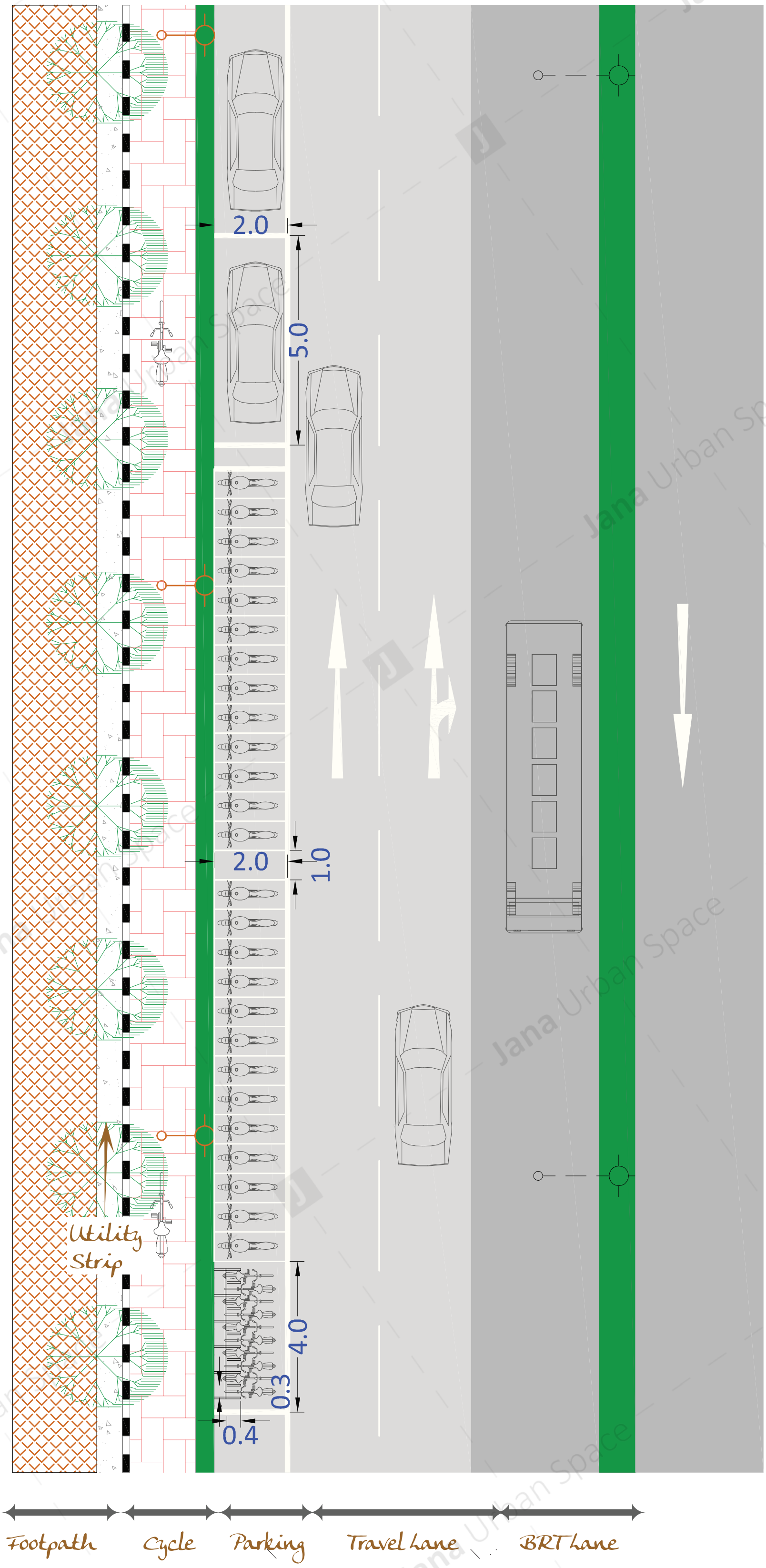


Bicycle pavement marking



8 - PARKING DETAILS - TWO WHEELER

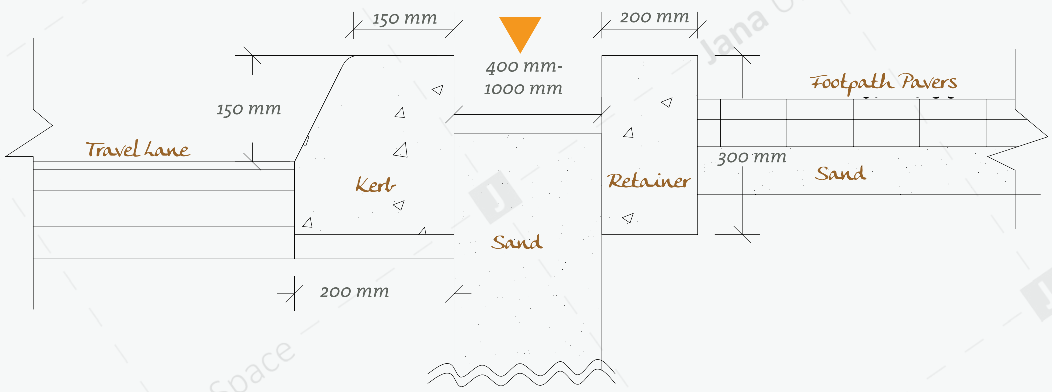
R-o-W Planning
Refer Section 2.3



9 - UTILITY STRIP/ PLANTING STRIP DETAILS

Utility Strip

Refer Section 2.4.3

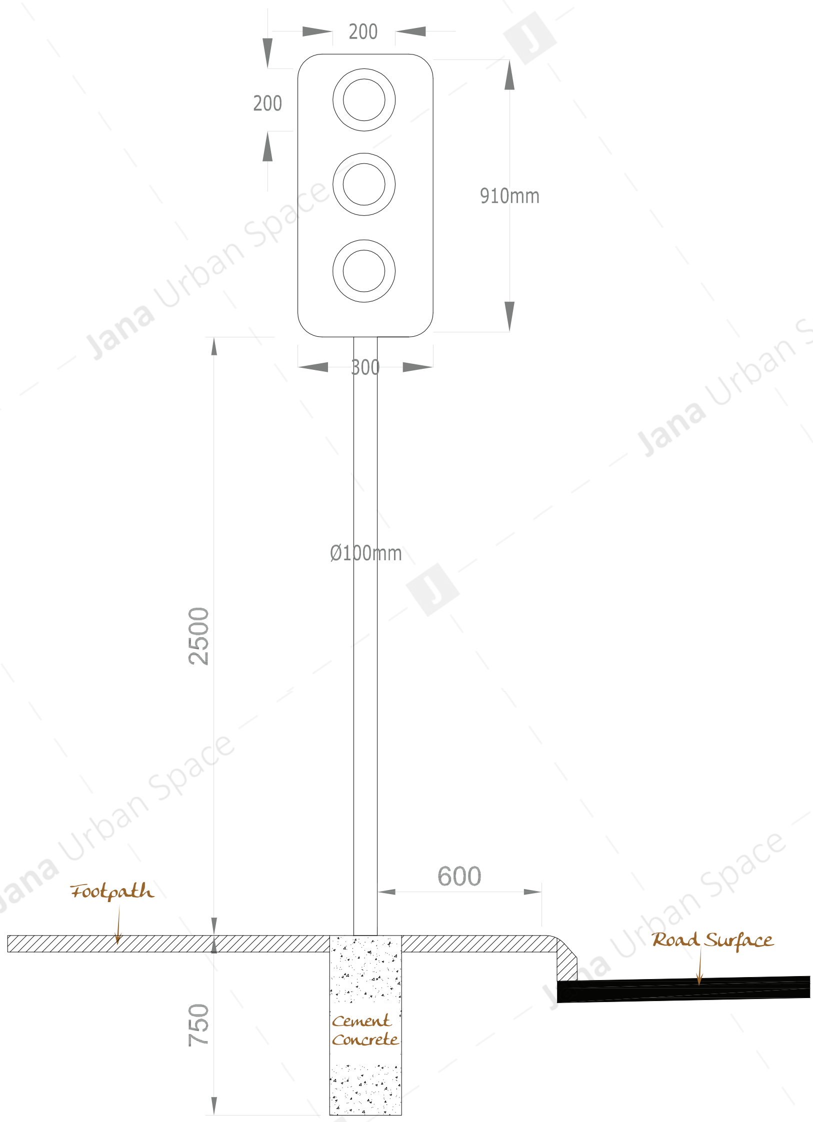


Details of Planting/Utility Strip

Image showing Planting Strip on Walton Road

10 - SIGNAL LOCATION IN AN INTERSECTION

Refer Section 2.5.3.2



Sectional View of Signal Pole

Dimensions are in mm unless otherwise specificed

11 - MULTI-USE POLE DIMENSIONS

Above Grade Street Fixtures

Refer Section 2.5.3.2

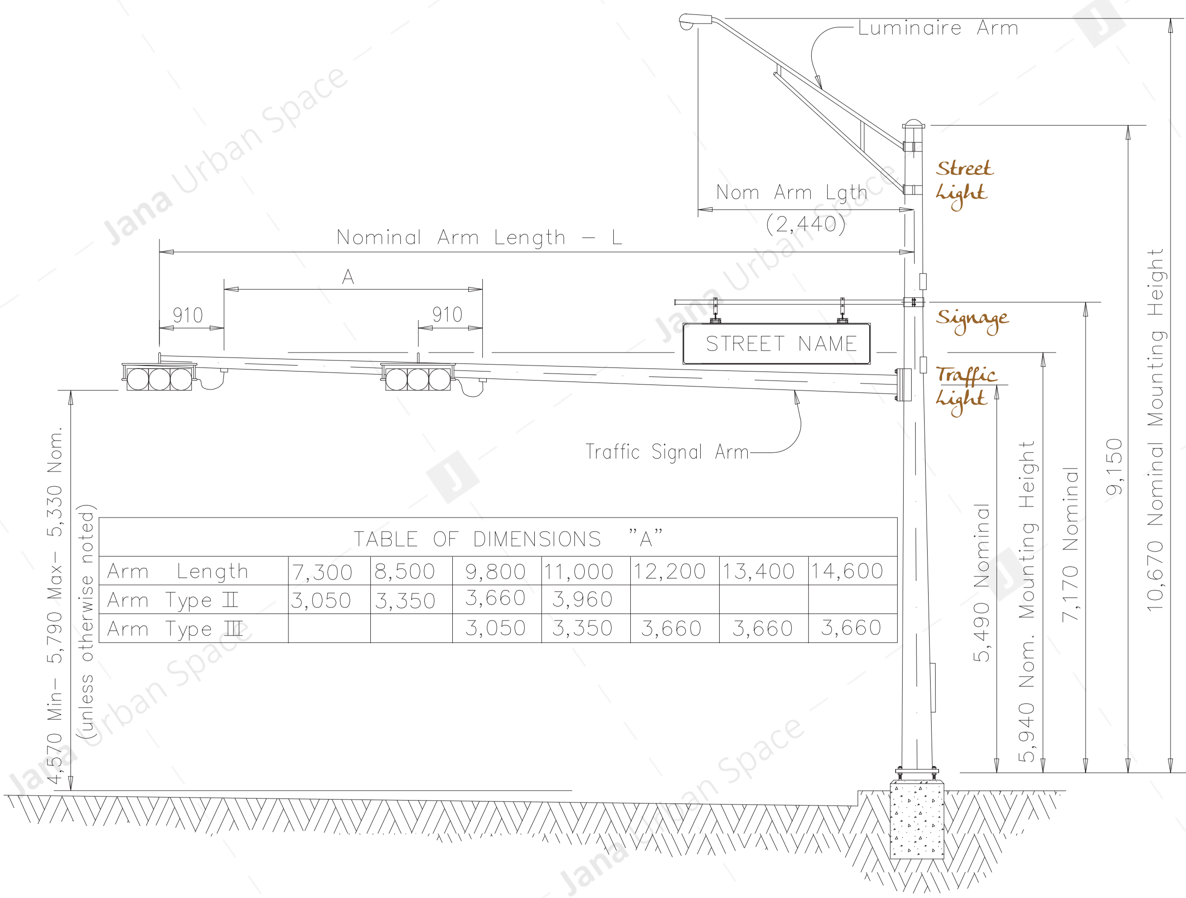


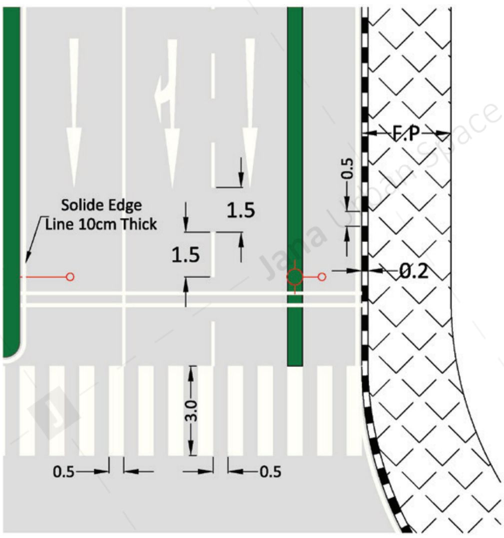
TABLE OF DIMENSIONS "A"							
Arm Length	7,300	8,500	9,800	11,000	12,200	13,400	14,600
Arm Type II	3,050	3,350	3,660	3,960			
Arm Type III			3,050	3,350	3,660	3,660	3,660

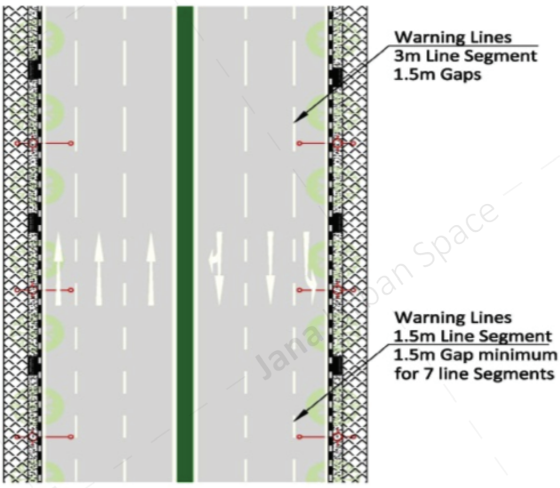
Source: Invicus Engg

ROAD MARKING

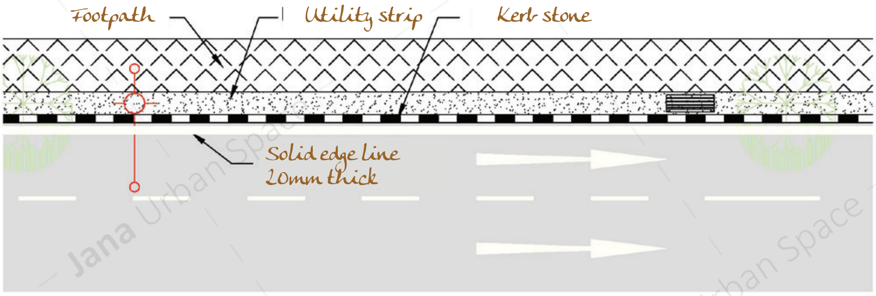
Above Grade Street Fixtures

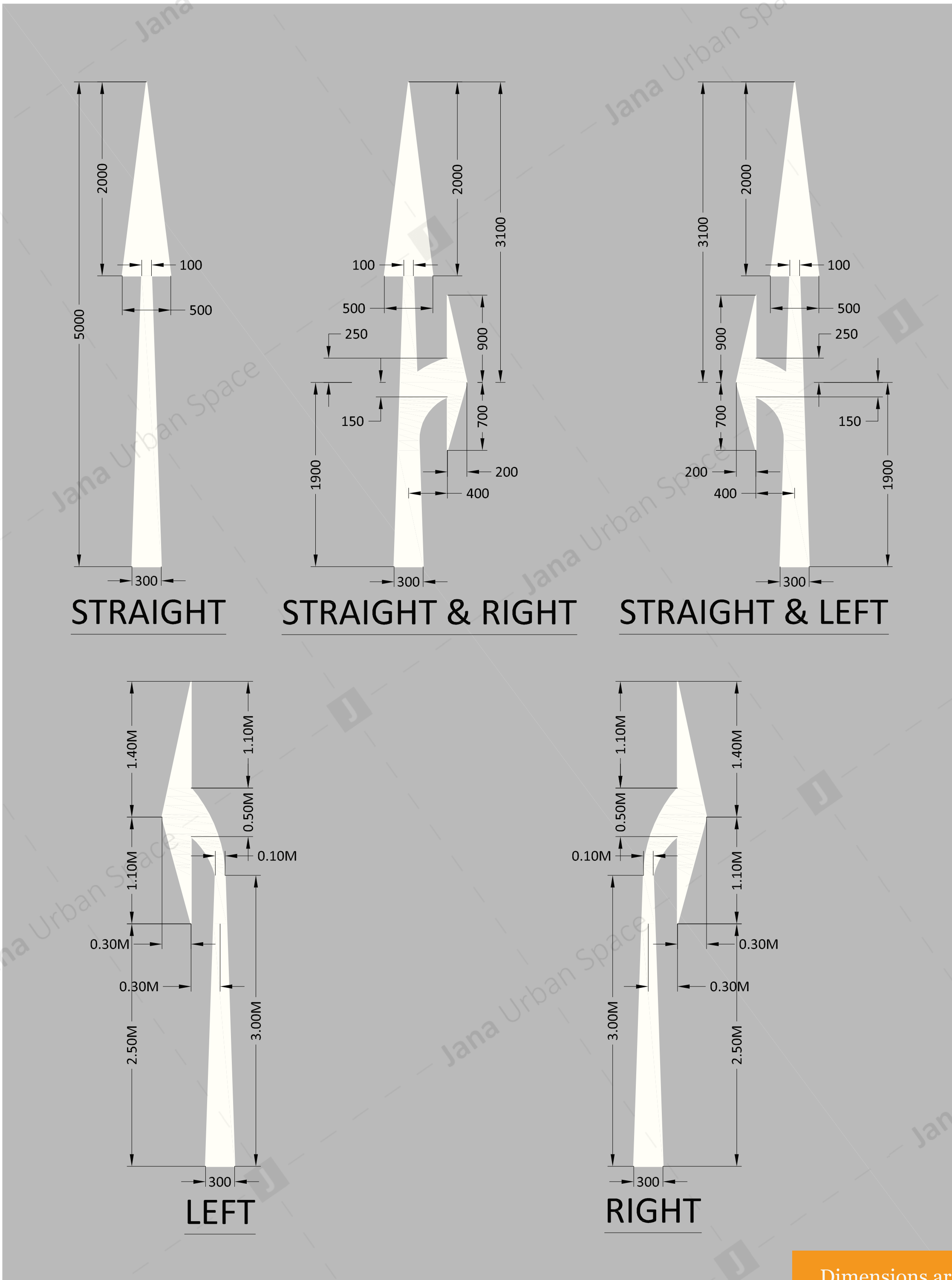
Refer Section 2.5.4.1





Dimensions are in metres

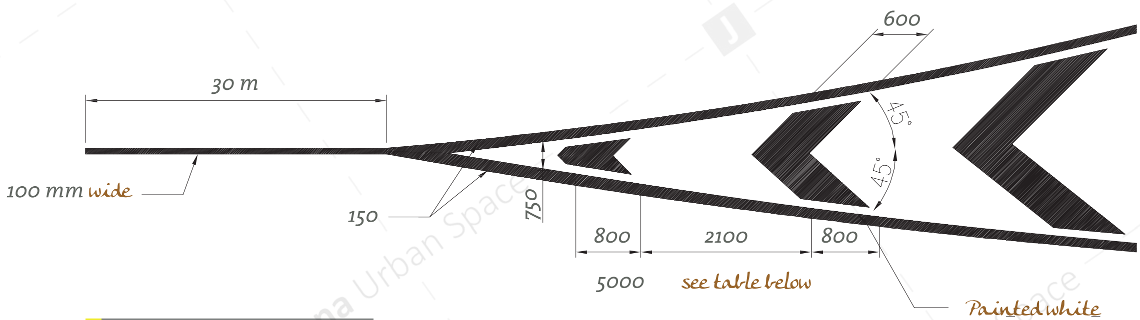




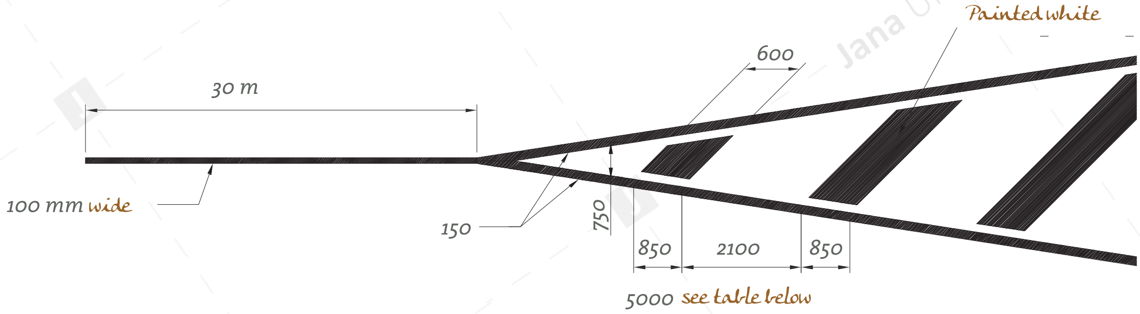
Dimensions are in mm unless otherwise specificed

14 - CHEVRON ROAD MARKINGS

Refer Section 2.5.4.3



Diagonal Markings



Chevron Markings

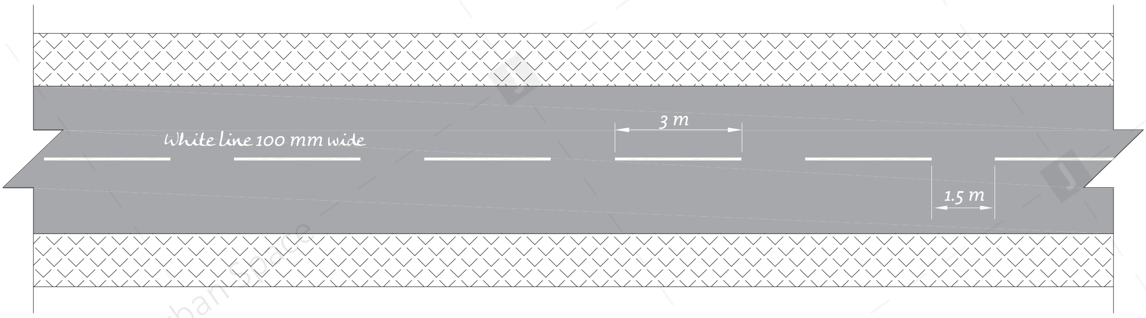
Dimensions are in mm unless otherwise specificed

SPACING BETWEEN DIAGONALS/CHEVRONS		
TOTAL LENGTH OF MARKING (m)	CLEAR SPACING BETWEEN DIAGONALS OR CHEVRONS (mm)	
	SPEED (<75 km/h)	SPEED (>75 km/h)
<6	2100	-
6 TO 22	3500	-
>22	5000	-
<10	-	4000
>10	-	6000

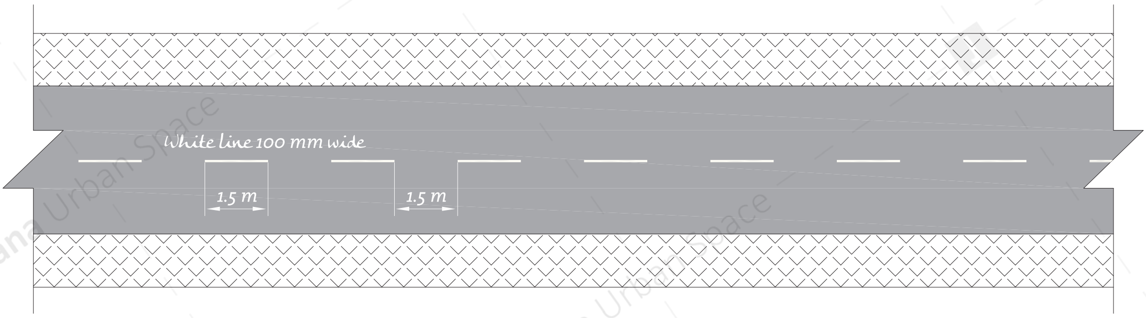
15 - CENTRE LINE MARKING

Above Grade Street Fixtures

Refer Section 2.5.4.3



Beyond intersections

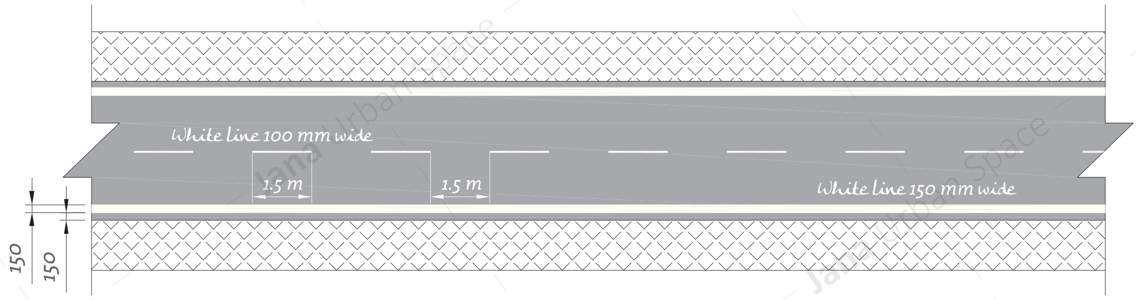


At intersections

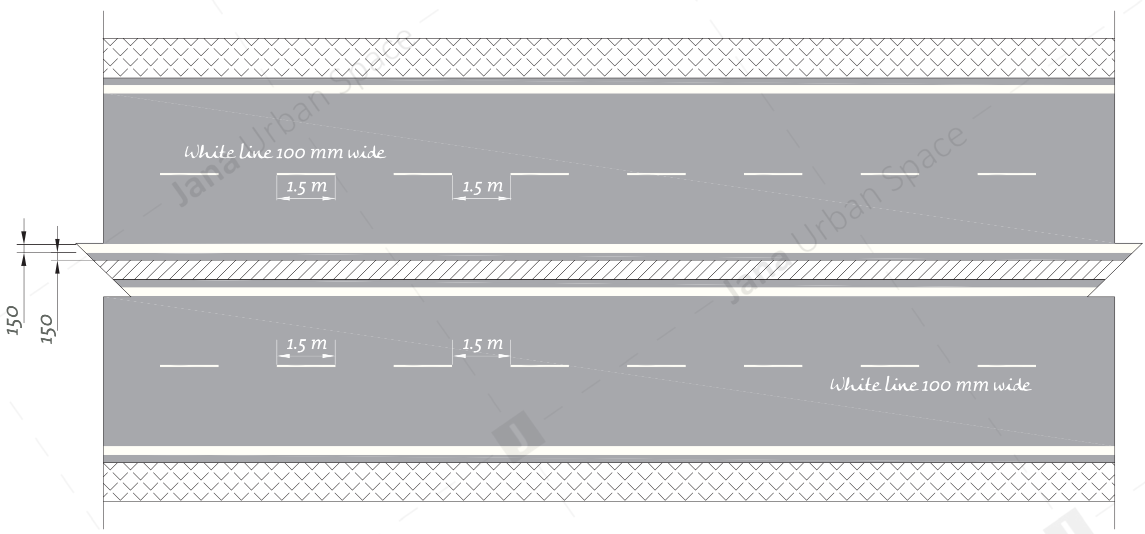
16 - EDGE LINE MARKING

Above Grade Street Fixtures

Refer Section 2.5.4.3



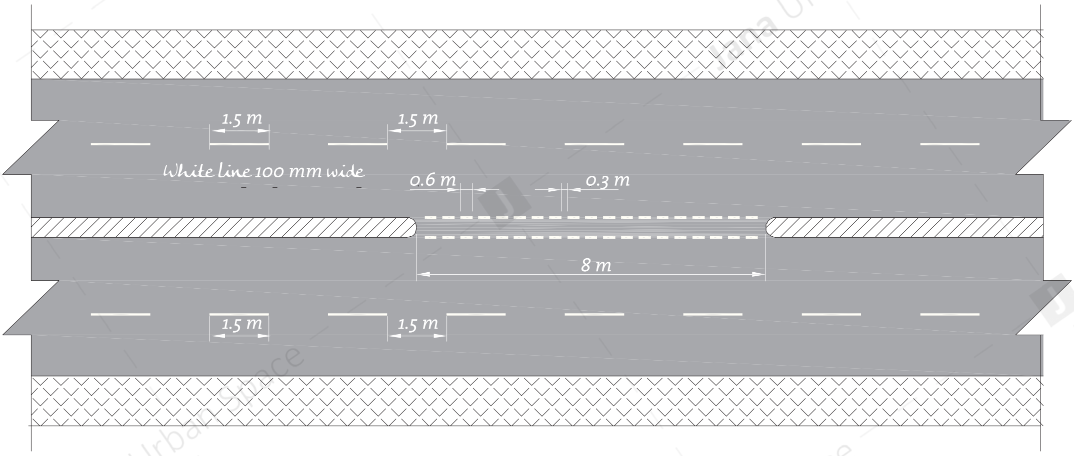
2 - Lane



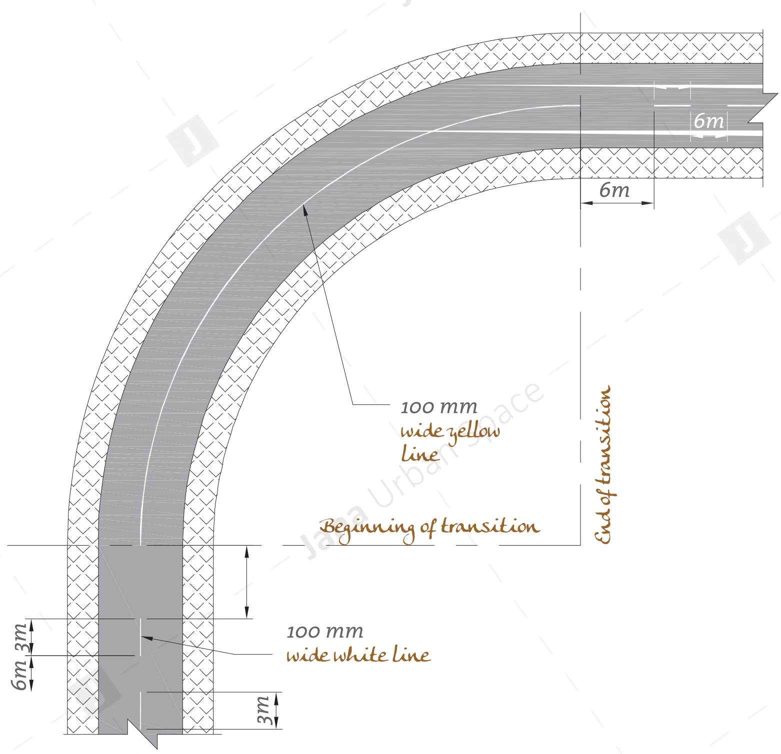
4-Lane with median

17 - EDGE LINE MARKING

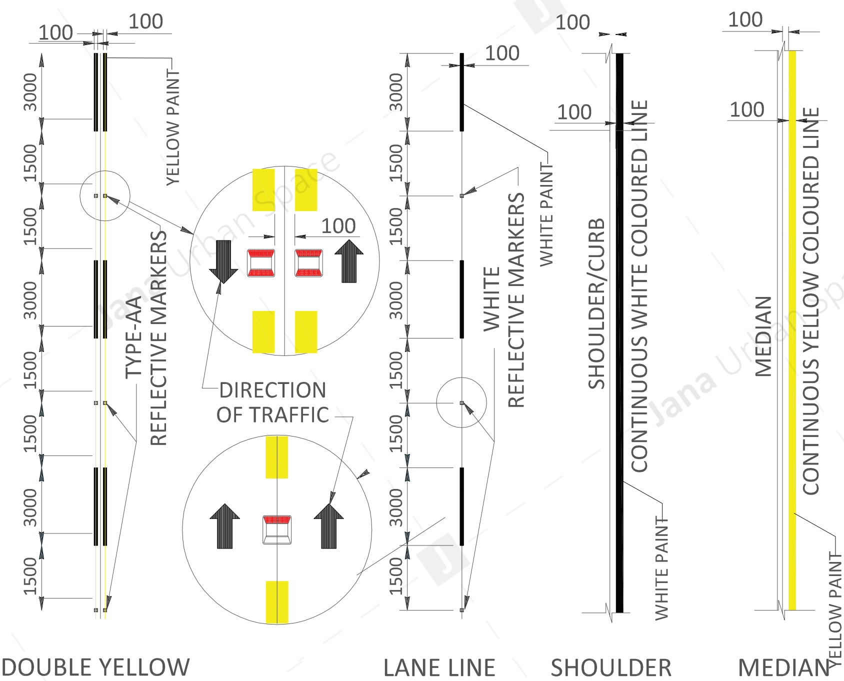
Refer Section 2.5.4.3



At median openings



Sharp curves (<230 m radius)(No overtaking zone)

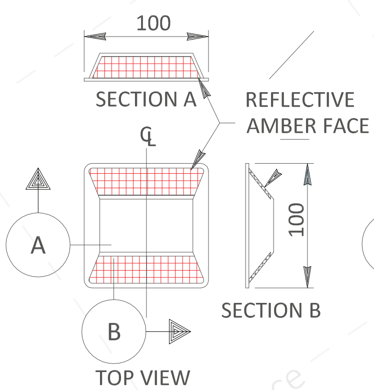


DOUBLE YELLOW CENTER LINE

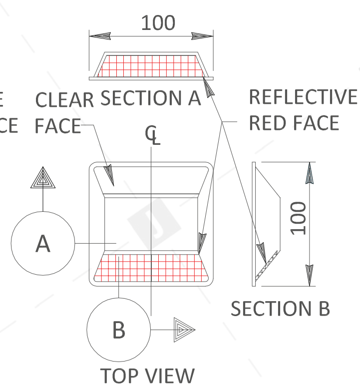
LANE LINE

SHOULDER LINE

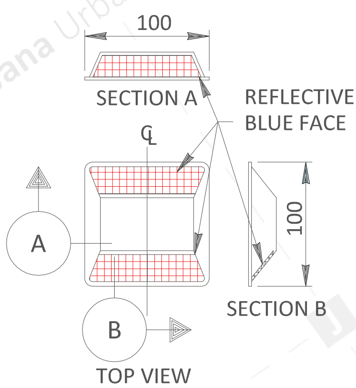
MEDIAN LINE



TYPE-AA
REFLECTIVE MARKER DETAILS



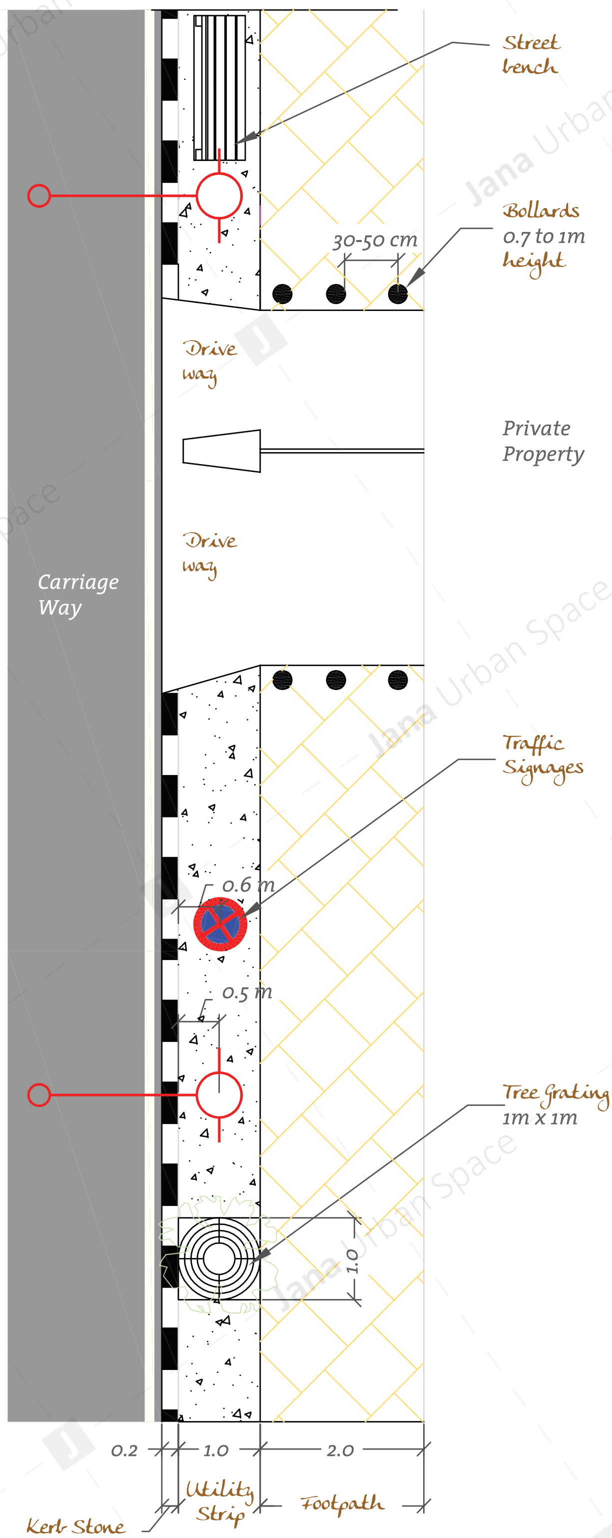
TYPE-CR
REFLECTIVE MARKER DETAILS



TYPE-BB
REFLECTIVE MARKER DETAILS

Dimensions are in mm unless otherwise specificed

Refer Section 2.4

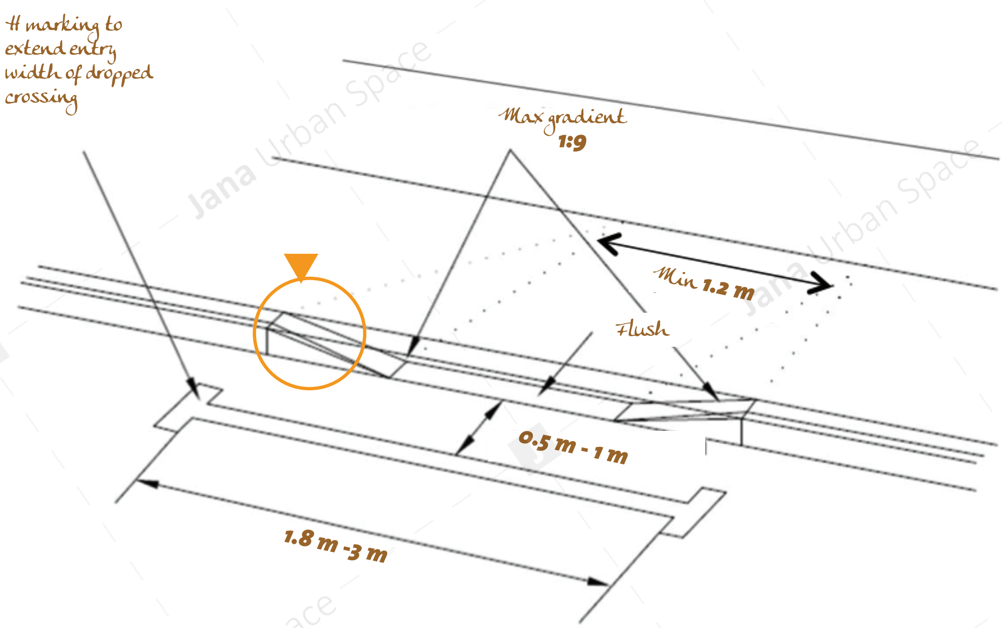


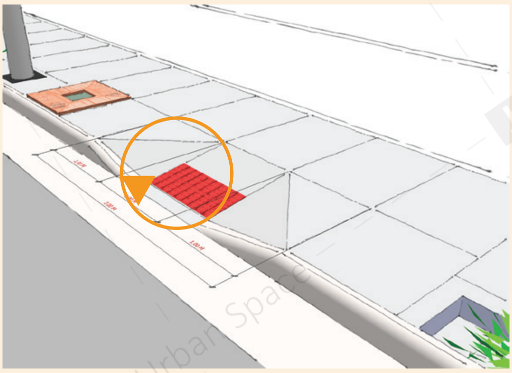
Dimensions are in m unless otherwise specificed

20 - DROP KERB

Above Grade Street Fixtures

Refer Section 2.4.2

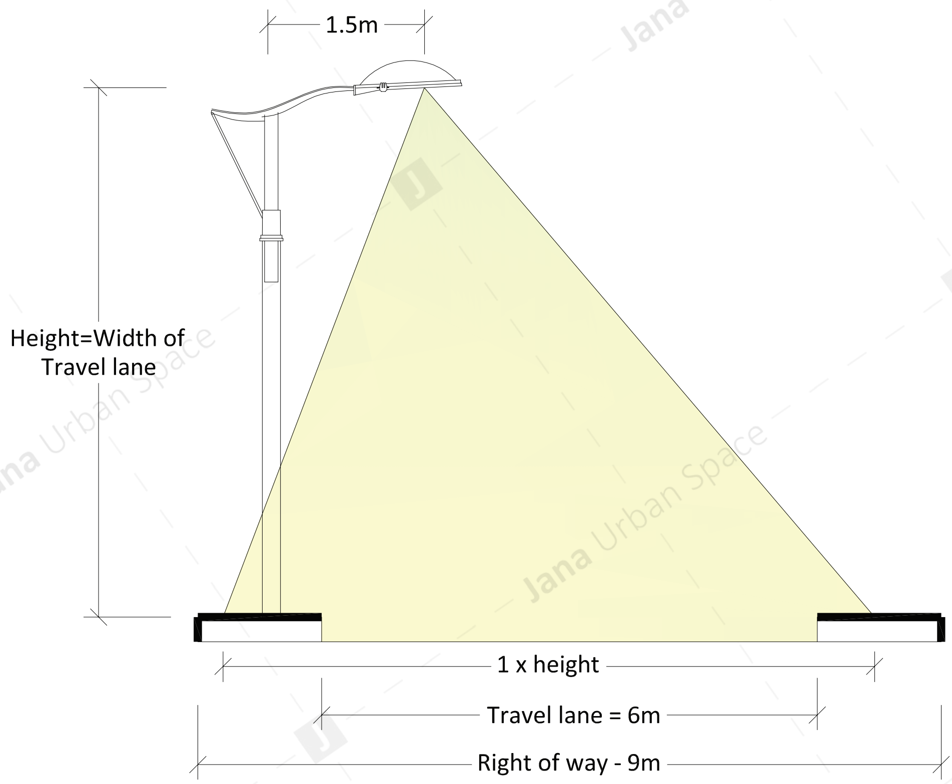




Drop kerb at an intersection

21 - STREET LIGHT

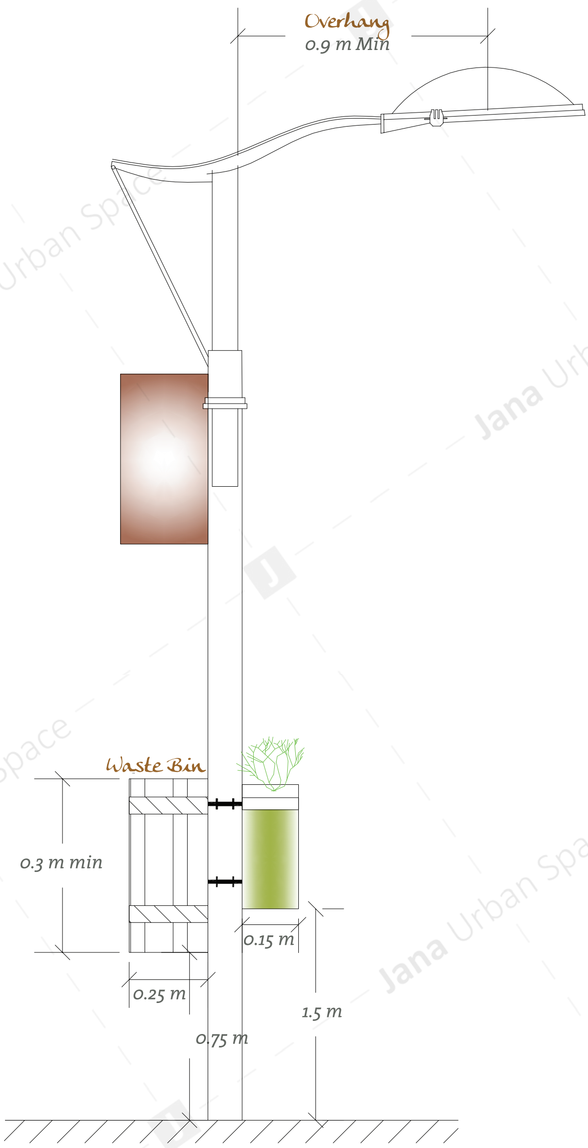
Refer Section 2.8.1



Sl no	Street Type	Recommended	Spacing in m	Staging Height in m
1	Sub-local	Single-sided	10	3
2	Local	Single-sided	10	6
3	Collector	Staggered/Opposite	15	9
4	Sub-arterial	Central	30	12
5	Arterial	Central + oppposite	30	12+6

22- STREET LIGHT EMBED WITH BIN

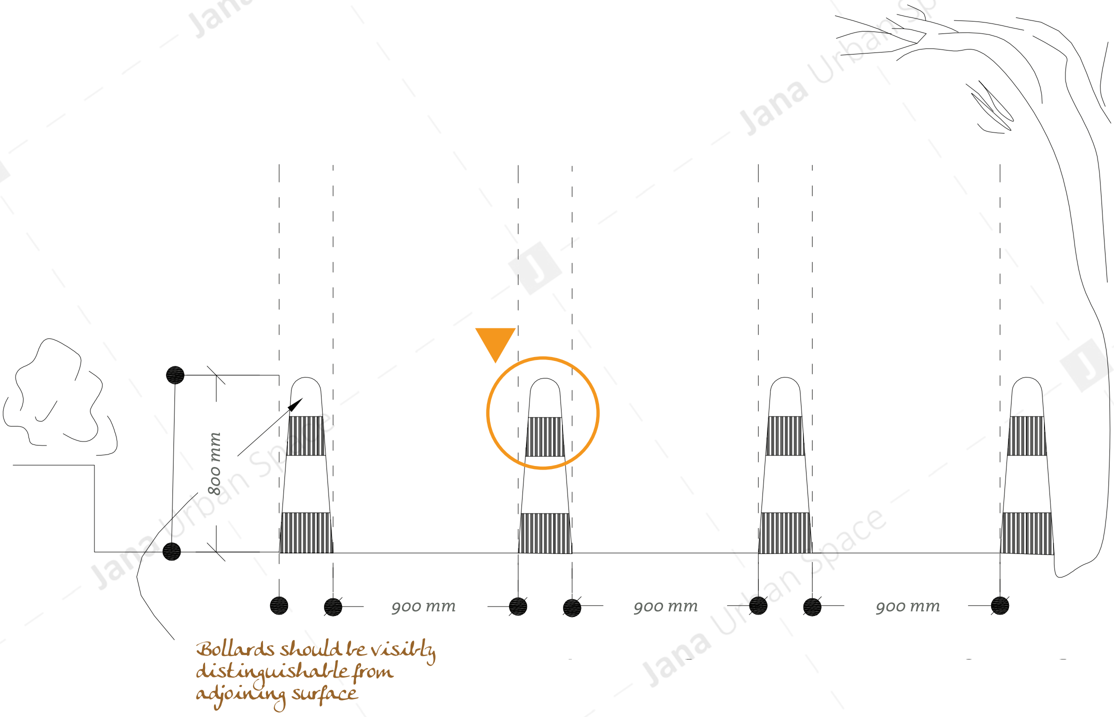
Refer Section 2.8.1



Light pole embedded with a waste bin and space for flower & plants

23 - BOLLARDS

Refer Section 2.8.2

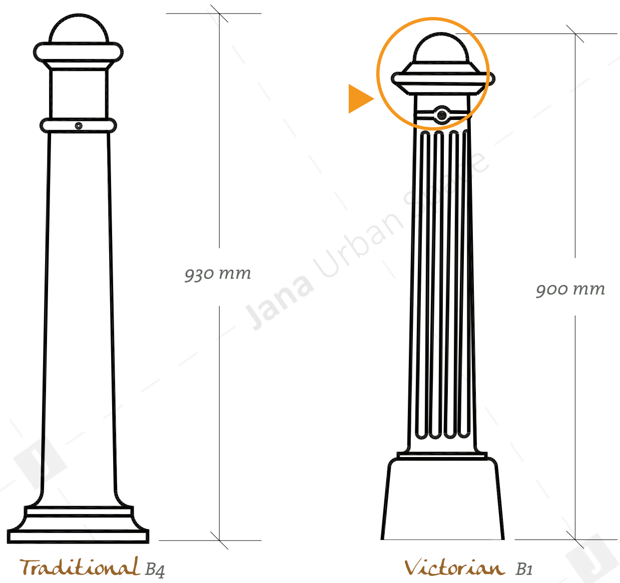


Bollards placed to restrict other vehicles entering bicycle track in Pune

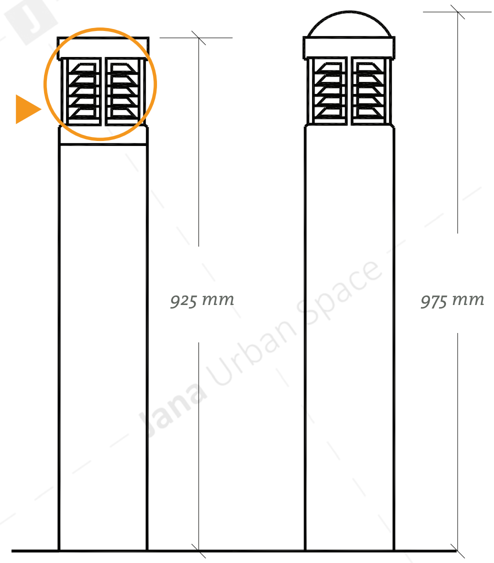
24 - BOLLARDS DETAILS

Above Grade Street Fixtures

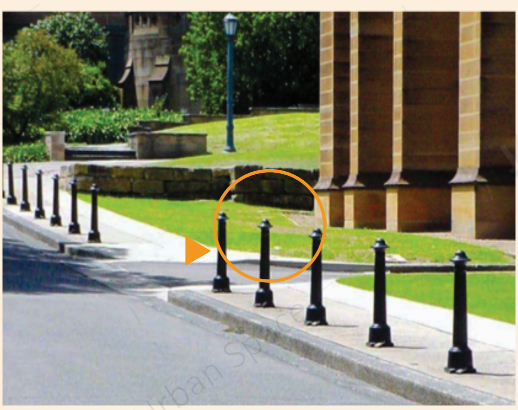
Refer Section 2.8.2



Classic Bollard



Light Bollard

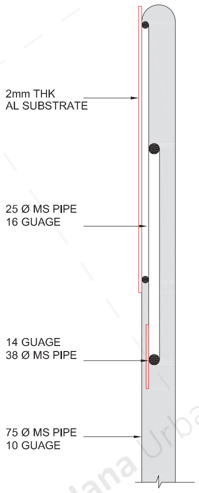


Victorian Bollard
(source: www.streetfurniture.net)

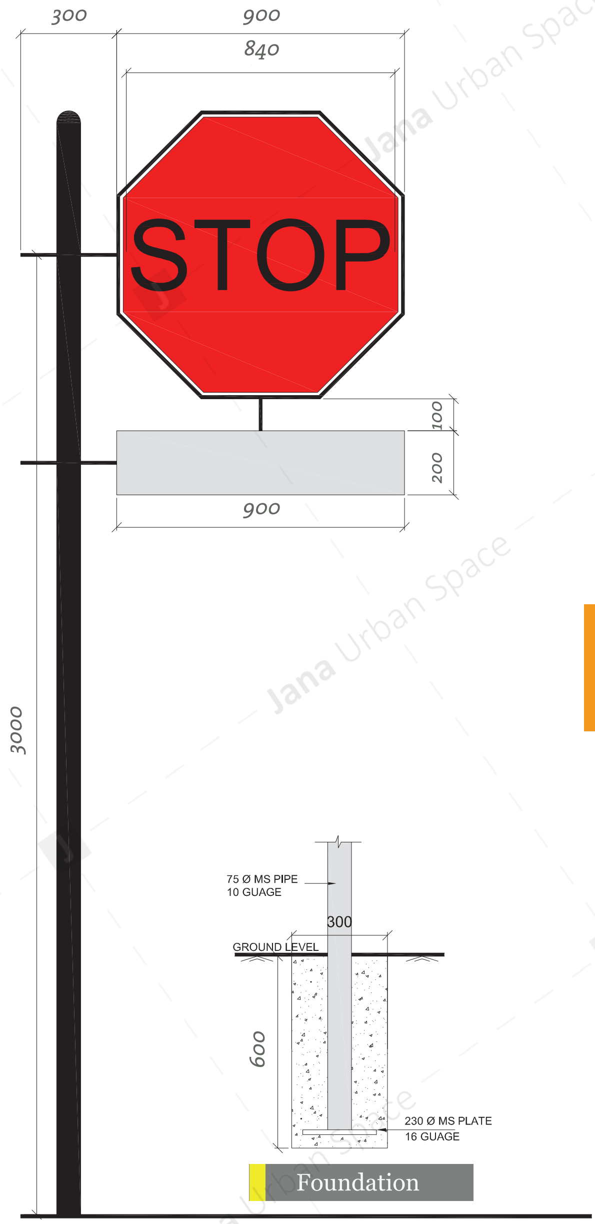
Reflector Bollard
(source: www.nolandgrab.org)

25 - STOP SIGN

Refer Section 2.8.9

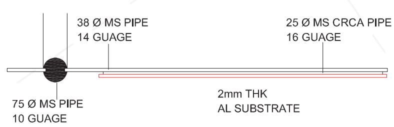


Section



Note :
All dimensions
are in mm

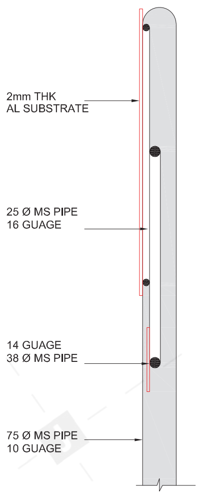
Foundation



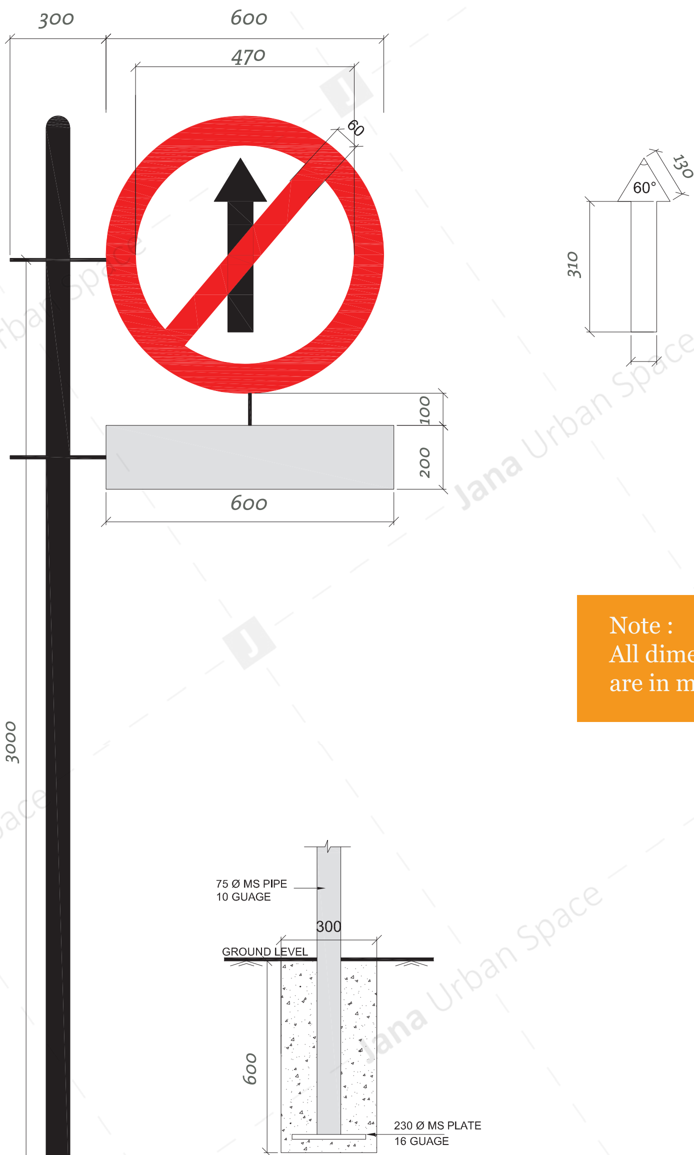
Plan

26 - NO ENTRY SIGN

Refer Section 2.8.9

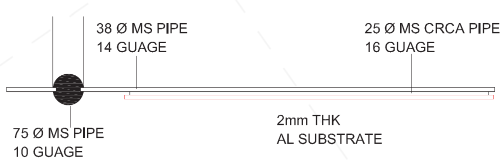


Section



Foundation

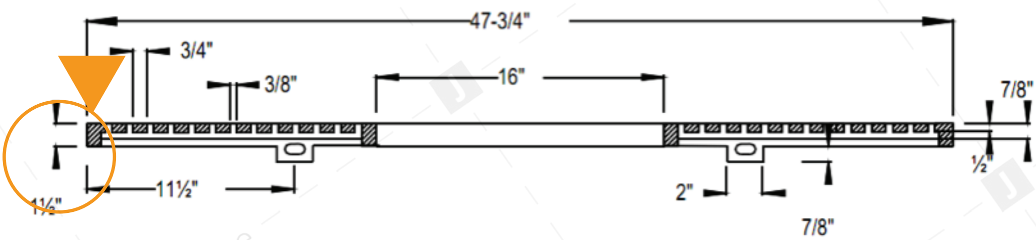
Note :
All dimensions
are in mm



Plan

27 - TREE GRATING

Refer Section 2.8.6



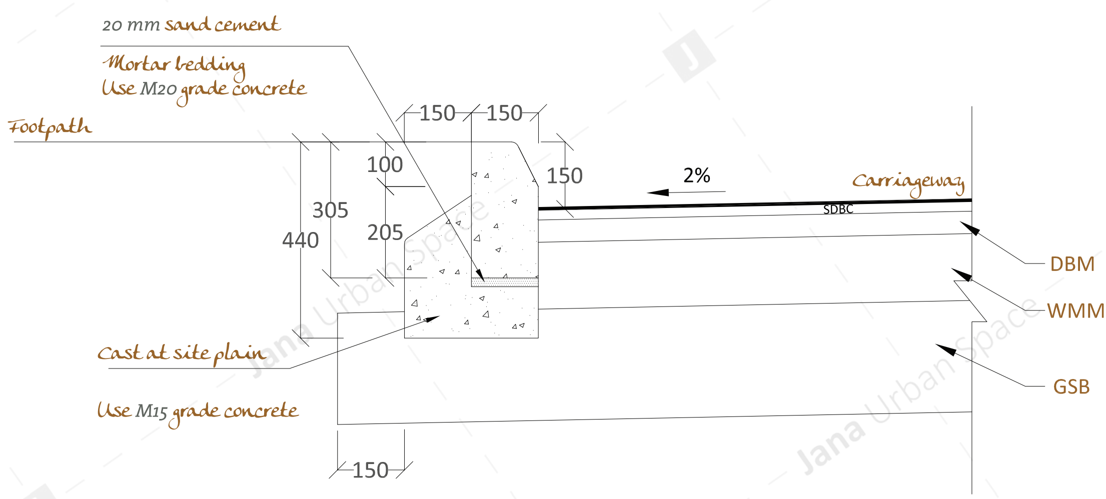
Note :
All dimensions
are in inches

Image showing a tree grating on a commercial corridor

28 - KERB DETAILS

Above Grade Street Fixtures

Refer Section 4.4 (a)



Note :
All dimensions are in inches

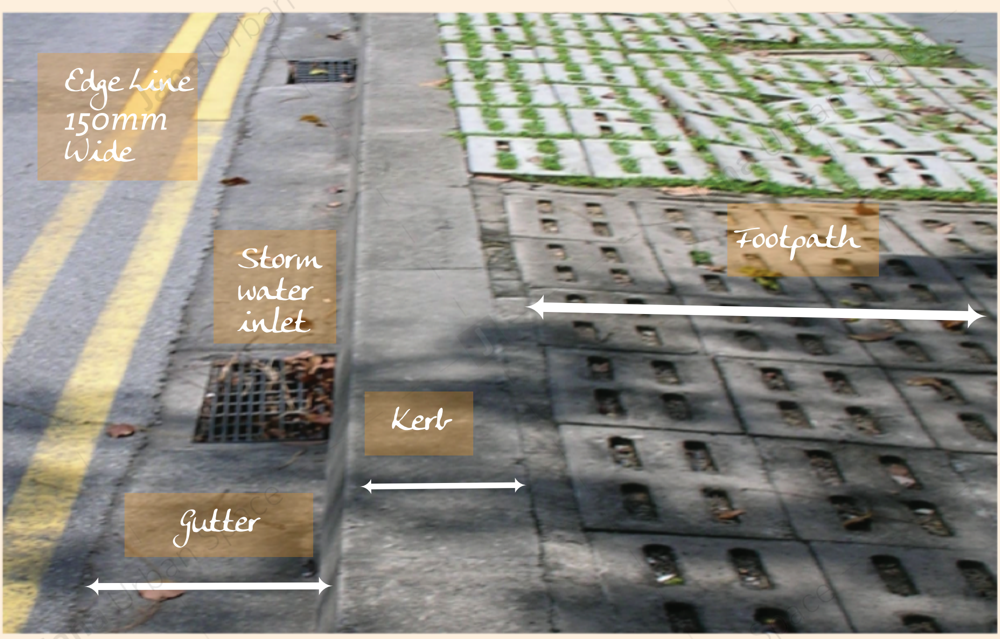
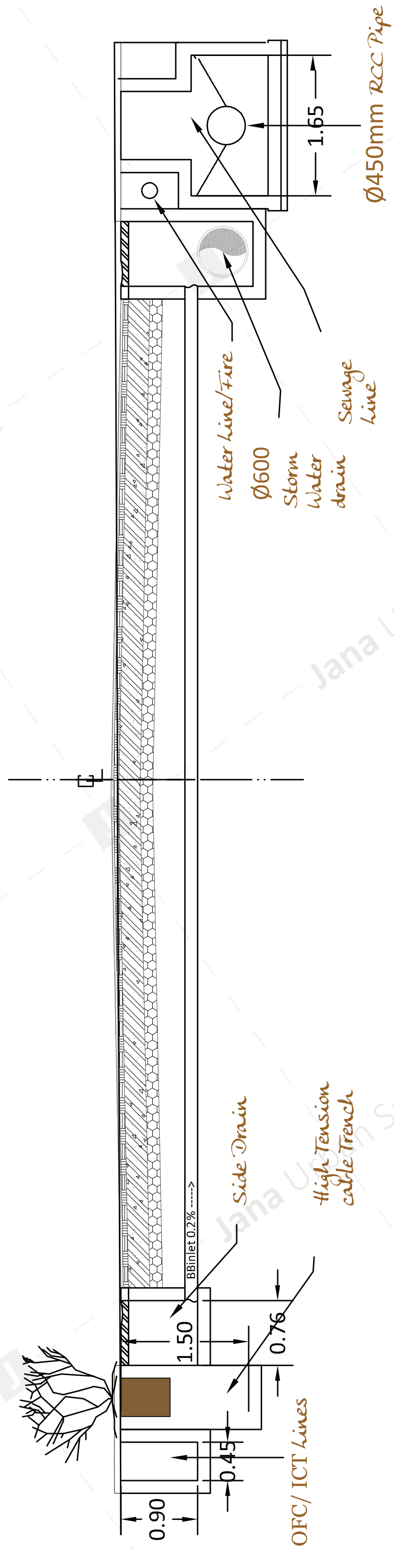


Image of kerb embedded with horizontal storm water inlet

29 - BELOW GRADE UTILITIES SNAPSHOT

Below grade utilities

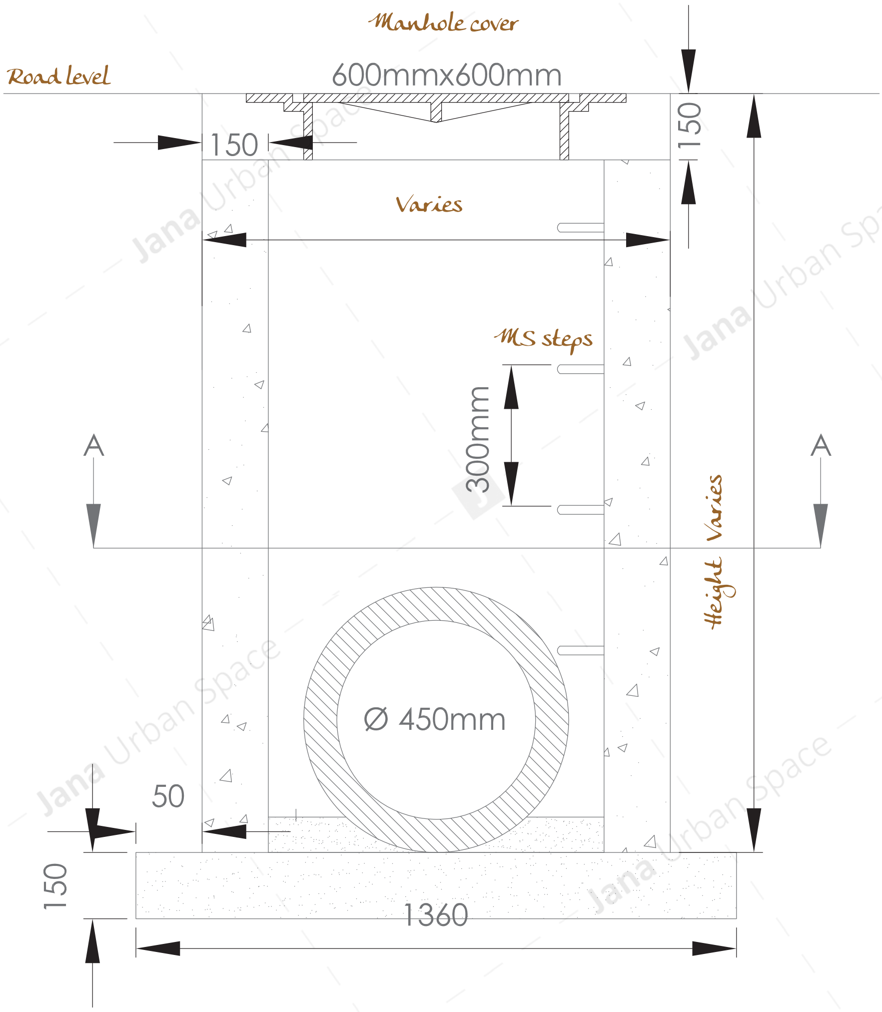
Refer Section 2.9



Note :
All dimensions
are in metres

30 - MANHOLE DETAILS

Refer Section 2.9.1 & 4.4 (b)

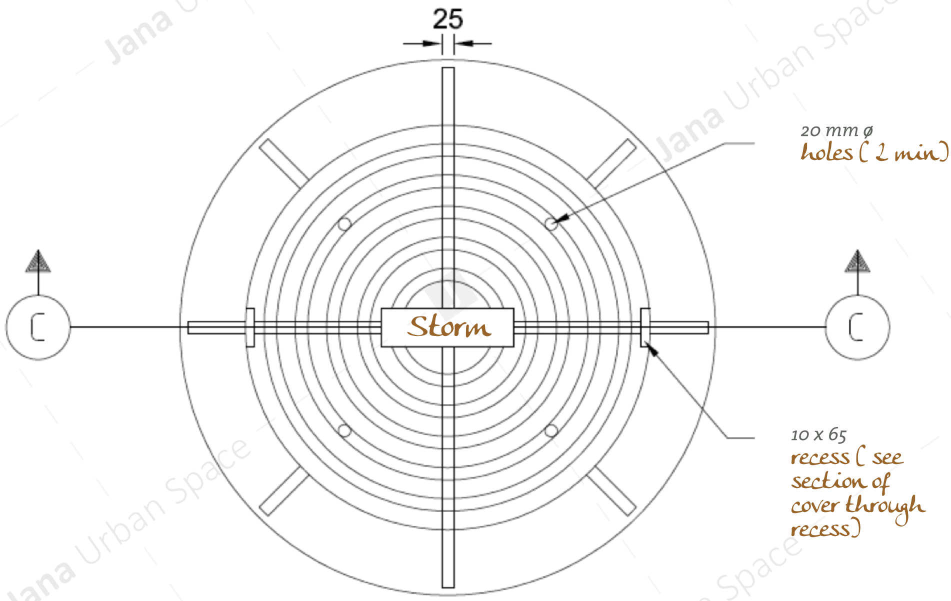


Note :
All dimensions are in mm

31 - MANHOLE DETAILS

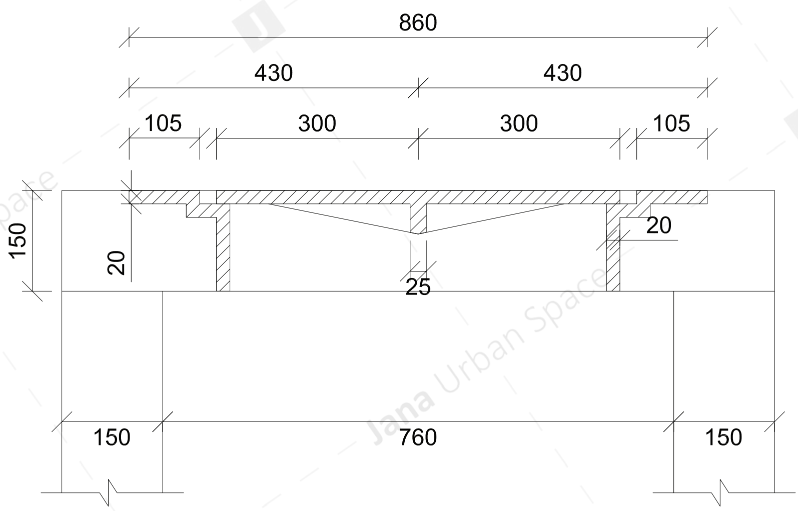
Below grade utilities

Refer Section 2.9.1, Image 2.69



Inlet Cover Plan

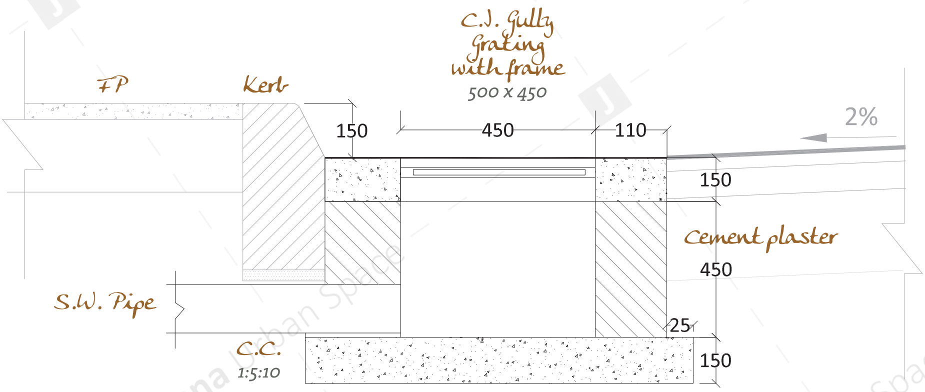
Note :
All dimensions
are in mm



SECTION C-C
Frame and Cover section

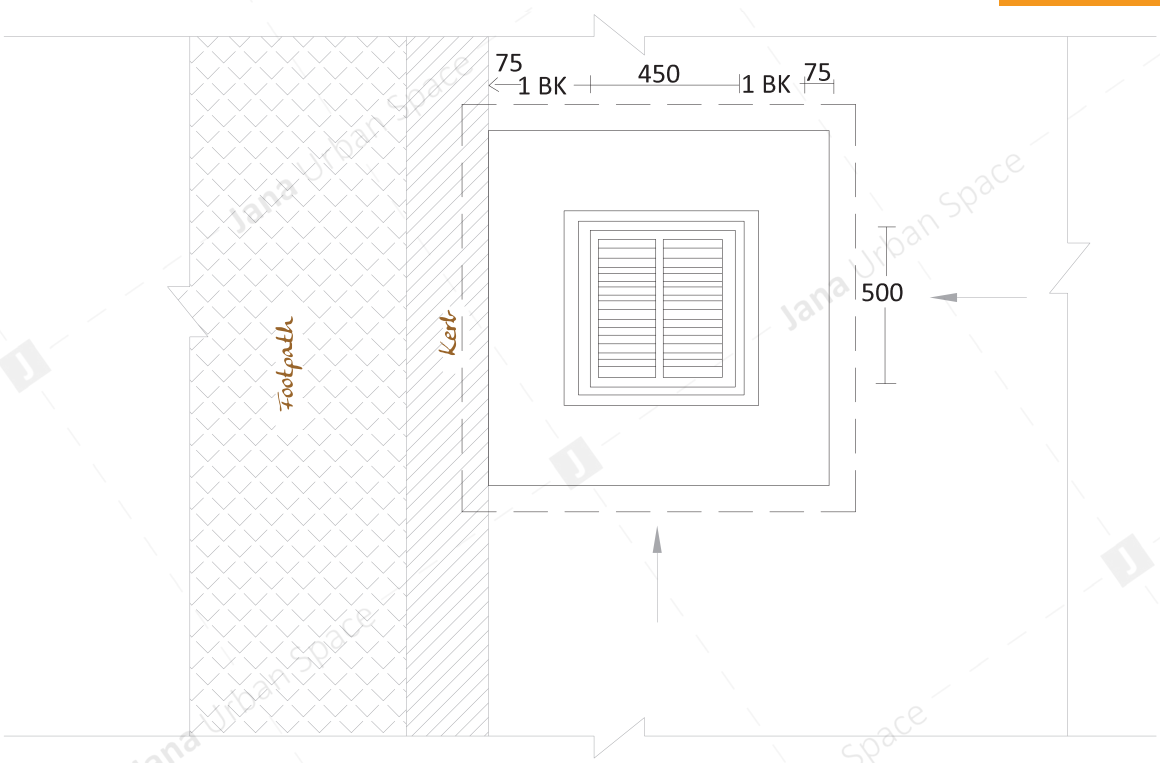
32 - HORIZONTAL GRATING DETAIL

Refer Section2.9.1 & 4.4 (b)



Cross-section of Horizontal Grating

Note :
All dimensions are in mm



Plan of Horizontal Grating

See image overleaf

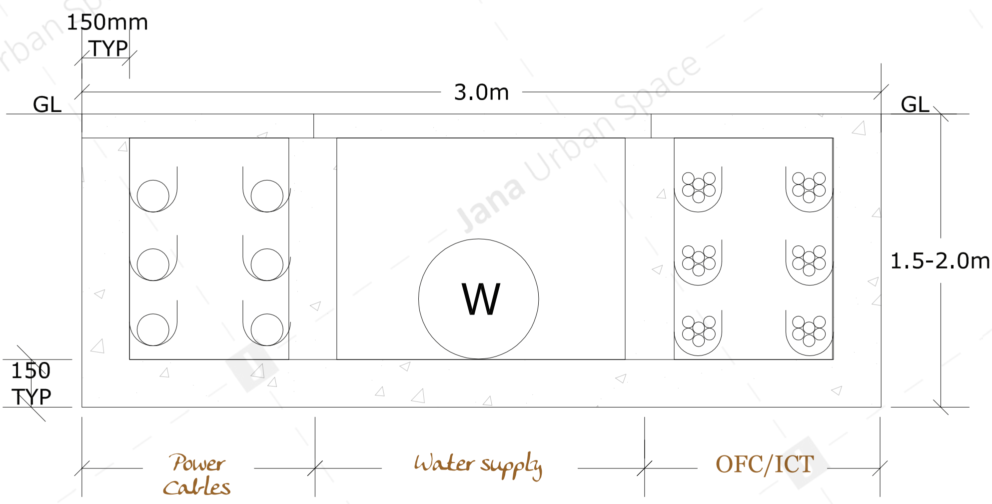
33- PRECAST DUCTS FOR UTILITIES

Below grade utilities

Refer Section 2.9.4

Underground utility access grills New York

Underground utility, Europe



CHAPTER 4

MATERIAL SPECIFICATIONS

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CHAPTER 4

MATERIAL SPECIFICATIONS

4.0 Material Specifications for Urban Road Traffic Lanes – New & Existing

Road composition comprises of layers of sub grade, granular sub base, wet mix macadam, dense bituminous macadam and bituminous concrete. The methodology and process of laying these layers are standardized by MoRTH. The table 4.1 gives general depths of the composition layers based on types of urban road. However, the numbers shown below vary based on traffic load conditions and the California Bearing Ratio (CBR), value of soil(refer to annexure vii for detailed information). Any new road should be laid layer by layer for longevity. Maintenance should be carried out once in 5 years thereafter, that requires laying of another course of BC. If the sub-grade is not laid properly, it results in rutting, hair cross and deformation occurs on the road surface.

Serial Number	Road components	Arterial Road (depth in mm)	Sub-Arterial Road (depth in mm)	Sub-Arterial Road (depth in mm)
1	Earthwork Excavation (excluding drain works)	700-925	700-865	700
2	Sub grade	500	200-300	500
3	Granular Sub base	200-260	200	200-260
4	Wet mix macadam	200-250	200-250	150-200
5	Dense Bituminous macadam	120	120	50
6	Bituminous concrete	40-50	40-50	40

Table 4.1>>
Components for Arterial, Sub-arterial and Collector Roads

Table 4.2>>
Components for
Local and Sub-local Roads

Serial Number	Bituminous concrete	Local Road (depth in mm)	Sub-local Road (depth in mm)
1	Earthwork Excavation	300	300
2	Metalling followed by a tac coat	200	200
3	Bituminous macadam	50	50
4	Semi dense bituminous concrete	25	25

The above mentioned details are meant for new developments where roads are being laid fresh. For the existing roads either re-metalling or overlays are appropriate. The use of cobblestones and pavers for travel lane surfaces on low traffic residential roads, is highly desirable for ease of restoration and maintenance (refer table 2.13, page 94).

4.1 >> Re-laying process for existing roads

a) *T*he old road surface should be roughened with pick axes before spreading the new metal. All dirt, dust, animal dropping, vegetation, etc, should be removed from the surface. Normally, there will be a thin crust of hard metal on the existing road and scarification would not be possible. So criss-cross lines are to be made with pick axes for the full width of the road diagonally - i.e., at about 450 to the centre line. These may be at 30 to 40cms intervals and about 40mm deep. These lines are the key to proper bonding between the existing and the new materials.

b) *S*ometimes, it becomes necessary to scarify the entire existing road and screen the metal removed. Chips from 20mm downwards are spread over the sub-grade so that a thick cushion is formed under the metal. It is then watered and the old metal is spread and managed in order to get the bigger metal to the top surface. New metal is now added and compacted. It may be observed that compaction is achieved very quickly as the base is wet and graded metal is used. Earth from the base fills up the interstices. Screenings may now spread over the surface and thoroughly watered and allowed for 24 hours before providing a final round of rolling. Traffic may be allowed on this surface only after two or more days.

An overlay is meant to restore or increase the load carrying capacity or life, which restores the riding quality of the pavement which might have suffered rutting and other deformations.

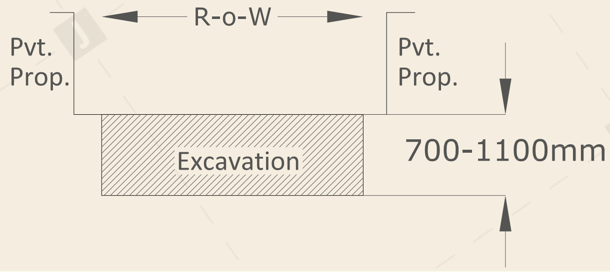
An overlay is meant to restore or increase the load carrying capacity or life, which restores the riding quality of the pavement which might have suffered rutting and other deformations. The overlay is not considered as a part of the periodic maintenance work, but it is an effort in the rehabilitation or strengthening of the road. Bituminous overlays on the existing black topped surfaces is the common practice in the country as these provide amenability to stage construction, is cheaper, and results in very little traffic dislocation. The alternatives available to make up for the additional thickness required are the following; (a) adding WBM over the existing bituminous surface and finishing; (b) making up the deficiency of thickness by 'built up spray grout' and finishing with bituminous surfacing; (c) providing an additional bituminous layer directly on the top of the existing surface and (d) providing cement concrete overlays (white topping).

4.2 >> Process and Specifications for laying new road - Bituminous

a. *E*arth Work

Excavation of earth needs to be carried out as per drawing and technical specification Clause 305.1, including setting out, scrapping/scarifying for top existing road surface (bitumen, metal surface), excavation for foundation,construction of shoring and bracing, removal of stumps and other deleterious materials, multiple handling and disposing away entire excavated earth away/debris from the site to designated areas by local authorities, including all lead and lifts, dressing of sides and bottom, and backfilling with approved material, dewatering if required as per direction of the engineer-in-charge. This excavation must also includes (arterial, sub-arterial and collector roads) for 'H2' type inlet, 'BB' type inlet, 'DIL' type inlet, storm manhole, sanitary sewer manhole, telecommunication ducts, telecommunication ditches, road and high tension cable ditch works.

Note: Type of inlets mentioned here are for reference, it varies from site to site. Reference – MoRTH No.300

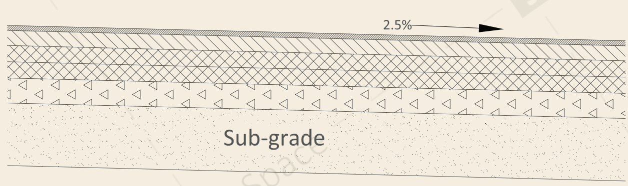


Section 4.1:Detail Earth-work excavation

b. *S*ub-grade

Preparing sub base by compacting of original ground with maximum of 6 passes of 8 to 10 tonnes power roller including filling depression occurring during rolling, cost of all labour, machinery etc. complete as per specs.

Reference - MORTH Specification No. 401

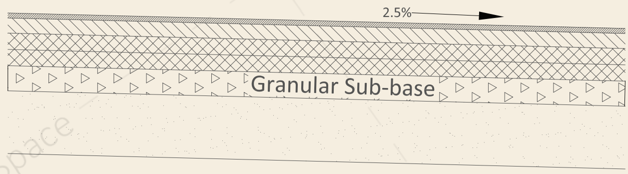


Section 4.2 : Detail for sub-grade

c. *G*ranular sub-base

Providing and laying of granular sub-base (GSB) of 200mm thick using good quality graded materials from approved source and mixed in the specified proportion, filling to be carried out by breaking clods, removal of roots and other organic materials, stacking and mixing in the specified proportion, spreading after mixing to required camber, leveling, watering with all leads to obtain moisture levels of mix as per codes at the time of compaction, and compacting each layer to obtain the required modified proctor density. The rate should include the cost of earth, compaction by rollers and water, cost of all labour, hire, fuel charges, all tools and plants, and all lead & lift and other incidental charges etc. complete as per drawing and technical specifications.

Reference - MORTH
Specification No. 401

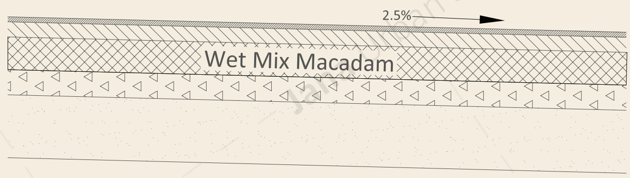


Section 4.3 : Detail for granular sub-base

d. *W*et-Mix Macadam:

Providing, laying, spreading and compacting to the required line camber level using graded stone aggregate wet mix macadam (wmm) of 200 mm thick as per specification including cost of all materials, laying uniform layer of base course, on a well prepared sub-base, and compacting with power roller to achieve the desired density, and with all lead metals sand and other materials, loading, unloading, stacking, spreading, etc., complete with all lead for the mix to the work spot as per specifications.

Reference - MORTH
Specification No. 406

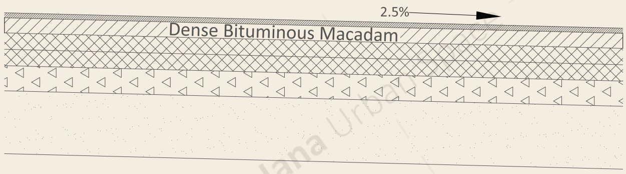


Section 4.4 : Detail for wet-mix macadam

e. *D*ense Bituminous Mix Macadam

Providing, laying and rolling with vibratory roller of built – up spray grout layer over prepared base consisting of a two layer composite construction of compacted crushed coarse aggregates, using motor grader for aggregates. Key stone chips spreader may be used with application of bituminous binder after each layer, and with key aggregates placed on top of the second layer to serve as a base conforming to the line, grades and cross – section specified, the compacted layer thickness being 120 mm complete as per specifications.

Reference - MORTH
Specification No. 506

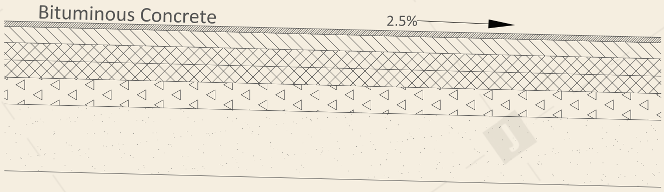


Section 4.5 : Detail for dense bituminous mix macadam

f. ***S***emi-dense Bituminous Concrete

Providing and laying semi dense bituminous concrete 25mm thick with 100-120 TPH batch type HMP, producing an average output of 75 tonnes per hour using crushed aggregates of specified grading, premixed with bituminous binder at 4.5 to 5% by weight of total mix and filler, transporting the hot mix to work site, laying with a hydro-static paver finisher with sensor control to the required grade, level and alignment, rolling with smooth wheeled, vibratory and tandem rollers to achieve the desired compaction.

Reference - MORTH
Specification No. 500.7



Section 4.6 : Detail for Semi-dense Bituminous Concrete

4.3 >> Process and Specifications for laying new road – Cement Concrete

For concrete roads, a layer of Dry Lean Concrete is to be provided over compacted earth on top of which M40 grade Cement Concrete is to be laid. A 150 micron thick Plastic sheet is to be laid over the quarry dust surface spread completely on the Road surface before laying concrete.

g. ***R***eady Mix Concrete

Providing & laying M30 grade 300 mm thick Ready mix controlled reinforced cement concrete, conforming to grades as specified in (IS 456 - 2000) as per specifications using 20mm down size aggregates at all levels including necessary shuttering, scaffolding, pumping, compacting with vibrations, curing. The rate is to include for providing construction joints, providing expansion joint of 25mm thick. Bituminous filler board and sealing joint with sealing compound as specified,

Contractor shall prepare bar bending schedule and fabrication shall be carried out as per bar bending schedules.

laying to required size and slope, MS rod for expansion/construction joint dowels, including PVC pipe complete. Alternate panels shall be concreted, panels sizes has to be approved by consultants.

h. *R*einforced Cement Concrete

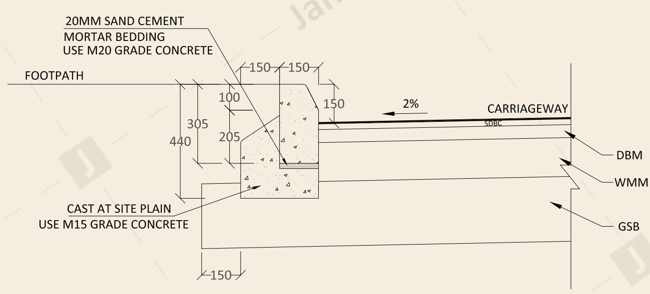
Providing & Fabricating reinforcement for R.C.C. in all items.Work to include transporting, decoiling, cutting, straightening, bending and placing in position at all levels & binding, with approved gauge binding wire. The rate should include cost of binding wire, chairs, spacers which will not be measured separately for payment, providing & placing CM cover blocks of suitable size to ensure specified cover to main reinforcement etc., complete all as per design, specifications, with all lead & lift for all materials & labour as directed, at all heights & locations. Quantity of steel as per drawing and with authorised overlaps only shall be measured and paid for. Contractor must prepare bar bending schedule and fabrication shall be carried out as per bar bending schedules.

4.4 >> Specifications for other items

a. *P*lain Cement Concrete Kerb

Providing and laying of precast concrete kerbs 914 x 315 x 150mm high in M20 Grade P.C.C on M-15 Grade foundation using 20mm aggregates, 150mm thick foundation and side support concrete laid manually as per drawings upto the required profile as per drawings including excavation, backfilling, form work, curing, including cost of all materials, labour, hire charges of machinery, loading, unloading, lead, lift, transporting, etc.

Reference - MORTH Specification No. 500.7

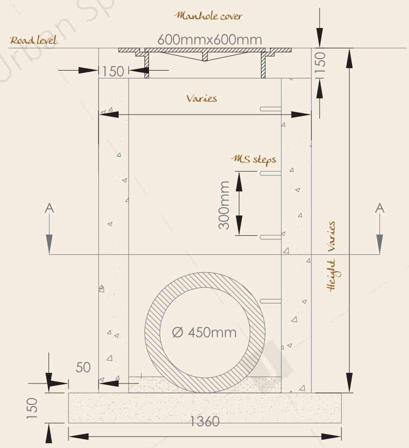


Section 4.7 : Plain Cement Concrete Kerb

b. *C*onstruction of Manholes

Miscellaneous items of construction and finishing for the all types of inlets and manholes for storm system as per engineering drawings provided by the engineer in charge or consultant, and specifications excluding concrete and steel but including cost of all required materials, labour etc., completed as per the detailed drawings. Supply and construction of manhole (on existing sewer or new sewer) up to a depth of 2000mm-4000mm with CBW (1:3) chamber of sizes mentioned below and 1400 mm length with circular shaft of brickwork (1:3), 275 mm thick RCC (M15) base slab placed over a layer of brick flat soling including M20 grade doubly reinforced RCC cover slabs 200 mm thick over chamber and 150 mm thick over shaft, having an opening for the manhole, formation of chamber at the invert with PCC (1:2:4) finished with 1.5 mm thick net cement finish over 15 mm thick plaster in cement and mortar (1:3) on all internal faces, including supplying, fitting and fixing of safety chain (for pipe dia 800 mm and above) and 600 mm dia clear opening (HD20) 20 empty capacity RCC manhole cover with frame as per IS12592, packed around with PCC 1:2:4, including shuttering, reinforcement, dismantling road crust, excavation in any kind of soil, with shoring and dewatering as required, back filling with consolidation, disposal of spoils-surplus earth as directed by the engineer.

Section 4.8 :
Typical Section &
Plan of a Manhole



c. Construction of Chambers

Miscellaneous items of construction and finishing for the all-access chambers for the telecommunication network and high tension cable system as per engineering drawings and specifications, excluding concrete and steel but including cost of all required materials, labour etc., completed as per the detailed drawings.

Image 4.9:
Access Chamber

d. Construction of cross drains

Providing and fixing MS grating (max weight : 15 kg/sft) for all cross drains as per drawings including red-oxide coating and related specification complete as per detailed design and drawings. Providing and fixing MS grating (max weight : 15 kg/sft) for MAJOR cross drain as per drawings including red-oxide coating and related specification etc., complete as per detailed design and drawings.

4.5 >> Material Specifications

a. *M*aterial details for Granular Sub-base

Scope

This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements of these specifications. The material shall be laid in one or more layers as sub-base or lower sub-base and upper sub-base (termed as sub-base hereinafter) as necessary according to lines, grades and cross -sections shown on the drawings or as directed by the engineer.

Materials

The materials to be used for the work shall be natural sand, moorum, gravel, crushed stone, or ca ombination thereof, depending upon the grading required. Materials like crushed slag, crushed concrete, brick metal and kankar may be allowed only with the specific approval of the engineer. The material shall be free from organic or other deleterious constituents and conform to one of the three grading given in Table 400-1(see overleaf), while the grading in Table 400-1 is in respect to close-graded granular sub-base materials, one each for maximum particle size of 75 mm, 53 mm and 26.5 mm, the corresponding grading for the coarse graded materials for each of the three maximum particle sixes are given in Table 400-2. The grading to be adopted for a project is to be as specified in the Contract.

Physical requirements

The material shall have a 10 per cent fines value of 50 kN or more (for sample in soaked condition) when tested in compliance with BS:812 (Part 111). The water absorption value of the coarse aggregate shall be determined as per IS:2386 (Pan 3); if this value is greater than 2 per cent, the soundness test shall be carried out on the material delivered to site as per IS:383. For Grading II and III materials, the CBR shall be determined at the density and moisture content likely to be developed in equilibrium conditions which shall be taken as being the density relating to a uniform air voids content of 5 per cent.

TABLE 400-1. GRADING FOR CLOSE-GRADED GRANULAR SUB-BASE MATERIALS

IS Sieve Designation	Per cent by weight passing the IS sieve Grading I	Grading 11	Grading III
75.0 mm	100	—	—
53.0 mm	80-100	100	—
26.5 mm	55-90	70-100	100-
9.50 mm	35-65	50-80	65-95
4.75 mm	25-55	40-65	50-80
2.36 mm	20-40	30-50	40-65
0.425 mm	10-25	15-25	20-35
0.075 mm	3-10	3-10	3-10
CBR Value (Minimum)	30	25	20

TABLE 400-2. GRADING FOR COARSE GRADED GRANULAR SUB -BASK MATERIALS

IS Sieve Designation	Per cent by weight passing the IS Sieve Grading 1	Grading II	Grading III
75.0 mm	100	—	—
53.0 mm		100	
26.5 mm	55-75	50-80	100
9,50 mm			
4.75 mm	10-30	15-35	25-45
2.36 mm			
0.425 mm			
0.075 mm	<10	<10	<10
CBR Value (Minimum)	30	25	20

Note : The material passing 425 micron (0.425 mm) sieve for all the ihrce grading! when vested according to IS : 2720 (Pan 5) shall have liquid limit and plasticity index not more than 25 and 6 per cent respectively.

b. *M*aterial details for Dense Bituminous Macadam

Bitumen:

The bitumen shall be paving bitumen of Penetration Grade complying with Indian Standard Specifications for "Paving Bitumen" IS: 73, and of the penetration indicated in Table 500-10 for dense bitumen macadam, or this bitumen as modified by one of the methods specified in Clause 521, or as otherwise specified in the tender contract. Guidance on the selection of an appropriate grade of bitumen is to be considered from the manual for construction and supervision of bituminous works.

Coarse aggregates:

The coarse aggregates should consist of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. They should be clean, hard, durable, of cubical shape, free from dust and of soft or friable matter, organic or other deleterious substances.

Where the contractor's selected source of aggregates have poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with an approved anti-stripping agent, as per the manufacturer's recommendations, without additional payment. Before approval of the source, the aggregates must be tested for stripping. The aggregates must satisfy the physical requirements specified in Table 500-8 (see overleaf), for dense bituminous macadam. Where crushed gravel is proposed for use as aggregate, not less than 90% by weight of the crushed material retained on the 4.75 mm sieve, are to have at least two fractured faces.

Fine aggregates:

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36mm sieve and retained on the 75 micron sieve. They should be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter.

TABLE 500-8. PHYSICAL REQUIREMENTS FOR COARSE AGGREGATE FOR DENSE GRADED BITUMINOUS MACADAM

Property	Text	Specification
Cleanliness (dust)	Grain size analysis [1]	Max 5% passing 0.075mm sieve
Particle shape	Flakiness and Elongation Index (Combined)[2]	Max 30%
Strength*	Los Angeles Abrasion Value[3] Aggregate Impact Value[4]	Max 35% Max 27%
Durability	Soundness:[5] Sodium Sulphate Magnesium Sulphate	 Max 12% Max 18%
Water Absorption	Water absoption[6]	Max 2%
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures[7]	Minimum retained coating 95%
Water Sensitivity	Retained Tensile Strength	Min80%

Notes: 1. IS:2386Part I   5. IS:2386Part5
2. IS: 2386 Part I   6. IS: 2386 Part 3
(the elongation test to be done only on non-flaky aggregates in the sample)
3. IS: 2386 Part 4*   7. IS: 6241
4. IS: 2386Part4*   8. AASHTOT283**
* Aggregate may satisfy requirements of either of these two tests.
** The water sensitivity test is only required if the minimum retained coating in the stripping lest is less than 95%.

Image 4.10 : Physical requirements for coarse aggregate for DBM

c.Semi-Dense Bituminous Concrete (source IRC 95-1987 & MoRTH)

Semi-dense bituminous concrete should be used as a wearing course and should not be laid directly over WBM or any granular base. The item should consist of mineral aggregates and appropriate binder mixed in a hot-mix plant and laid with a paver on a previously prepared base in accordance with the specifications and conforming to the lines, grades and cross-sections.

Considering that these are high cost specifications, semi-dense bituminous concrete mixes should be properly designed so as to satisfy certain criteria needed to assure satisfactory performance and durability. The mix as designed and laid should satisfy the requirements given in Table 4.3 based on Marshall Method.

Table 4.3>>
Requirements of the mix

1	Number of compaction blows on each end of Marshall	50
2	Marshall stability in kg (Minimum)	340
3	Marshall flow (mm)	2--4
4	Percent voids in mix	5--10
5	Percent voids in mineral aggregate filled with bitumen	55-75
6	Binder content as percent by weight of total mix (to be decided based on Marshall design method)	4.5--6.0

Notes:
1. It is suggested that higher stability values consistent with other requirements should be achieved as far as possible
2. At bus stops, parking areas and roundabouts, near minimum flow values should be adopted
3. The attempt should be to have well graded aggregate and the percent voids in the mix closer to the lower limit

Materials

In order to satisfy the requirements spelt above, the SDBC mix should consist of coarse aggregate, fine aggregate and filler in suitable proportions and mixed with sufficient binder content. True and representative samples of the aggregates proposed to be used on the specific job should be tested in the design laboratory and proper blend of the aggregates should be worked out so that the gradation of the final composition will satisfy either of the three limits set forth in Table 4.4.

Table 4.4>>
Gradation of aggregate in the final mix

Grading number	1	2	3
Sieve size	(Percent passing by weight)		
22.4 mm		100	100
13.2 mm	100	85--100	79--100
11.2 mm	88-100	70-92	68-90
5.6 mm	42-64	42-64	33--55
2.8 mm	22-38	22-38	22-38
710 um	11--24	11--24	6--22
355 um	7--18	7--18	4--14
180 um	5--13	5--13	2--9
90 um	3--9	3--9	0--5

Grading No.1 is suggested for compacted thickness of 25mm and grading No.2 and 3 for compacted thickness of 25-40mm.

The exact bitumen content required is to be arrived at as per Marshall procedure for the aggregategradation worked out in the laboratory and by using the same paving bitumen proposed to be used in the field.

The material should further satisfy the following physical requirements.

Bitumen:

The bitumen shall be paving bitumen of suitable penetration grade within the range of S 35 to S 90 or A 35 to A 90 (30/40 to 80/100) as per IS:73 'Paving Bitumen'. The actual grade of bitumen to be used should be decided by the engineer-in-charge, appropriate to the region, traffic, rainfall and other environmental conditions.

Coarse aggregate:

The coarse aggregate should be crushed material retained on 2.8mm sieve and crushed stone, crushed slag, crushed gravel (shingle) and consist of angular, clean, tough and durable fragments, free from disintegrated pieces and organic or deleterious matter and adherent coatings. The aggregate should be preferably be hydrophobic and of low porosity. When hydrophilic aggregates are used, the bitumen is to be treated with anti-stripping agents of approved quality in suitable doses. The aggregate should satisfy the physical requirements as given in Table 4.5.

Table 4.5>>
Gradation of aggregate in the final mix

Grading number	1	2	3
Sieve size	(Percent passing by weight)		
22.4 mm		100	100
13.2 mm	100	85--100	79--100
11.2 mm	88-100	70-92	68-90
5.6 mm	42-64	42-64	33--55
2.8 mm	22-38	22-38	22-38
710 um	11--24	11--24	6--22
355 um	7--18	7--18	4--14
180 um	5--13	5--13	2--9
90 um	3--9	3--9	0--5

Fine aggregates:

The fine aggregate should be the fraction passing 2.8mm sieve and retained on 90mm sieve, and should consist of crushed screenings, natural sand or a mixture of both. It should be clean, hard, durable, uncoated, dry and free from injurious, soft or flaky pieces and organic ordeleterious matter.

Filler:

The requirement of filler in semi-dense bituminous mixes should normally be met by the material passing 90 mm sieve in fine aggregate. In case the fine aggregate is deficient in material passing 90 mm sieve, extra filler shall be added. The filler shall be an inert material, the whole of which passes 710 mm sieve, atleast 90 percent passes 180 mm sieve and not less than 70 percent passes 90 mm sieve. The filler should be stone dust, cement hydrate lime, flyash or other approved non-plastic mineral matter.

d. Wet Mix Macadam Sub-Base/Base

Scope

This work consists of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared subgrade/sub -base/base or existing pavement as the case may be, in accordance with the requirementsof these specifica-tions. The material is to be laid in one or more layers as necessary to the lines, grades and cross -sections shown on the approved drawings or as directed by the engineer.

The thickness of a single compacted wet mix macadam layer shall not be less than 75 mm. When vibrating or other approved types of compacting equipment is used, the compacted depth of a single layer of the sub-base course may be increased to 200 mm upon approval of the engineer.

Aggregates -Physical requirements:

Coarse aggregates shall be crushed stone. If crushed gravel/shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4,75 mm sieve shall have-at least two fractured faces. The aggregates must conform to the physical requirements set forth in Table below.

Image 4.11:
Physical requirements for coarse aggregate for WMM
(source: Table 400-10. MoRTH)

	Test	Test Method	Requirements
1.	*Los Angles Abrasion value or * Aggregate Impact value	IS: 2386 (Part-4) IS: 2386 (Part-4) or IS: 5640	40 per cent (Max) 30 per cent (Max)
2.	Combined Flakiness and Elongation Indices (Total)	IS: 2386 (Part-4)	30 per cent (Max)

* Aggregate may satisfy requirements of either of the two tests.

Image 4.12:
Grading requirements of aggregates for WMM
(source: Table 400-10, MoRTH)

If the water absorption value of the coarse aggregate is greater than 2 per cent, the soundness test shall be carried out on the material delivered to site as per IS: 2386 (Part-5).406.2.1.2.

Grading requirements: The aggregate shall conform to the grading given in Table below.

IS Sieve Designation	Per cent by weight passing the IS sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	---
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600.00 micron	8-22
75.00 micron	0-8

Materials finer than 425 micron should have Plasticity Index (PI) not exceeding 6. The final gradation approved within these limits shall be well graded from coarse to fine and are not to vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa.

4.6 >> General Requirements for Bituminous Pavement Layers

(Source – MoRTH, section 500)

General

Bituminous pavement courses shall be made using the materials described in the following specifications. The use of machinery and equipment mentioned in various clauses of these specifications is mandatory. Details of the machinery and equipment are available in the manual for construction and supervision of bituminous works. Equipment mandatory for any particular project shall be in accordance with the contract for that project.

Materials

Binder: The binder shall be an appropriate type of bituminous material complying with the relevant Indian Standard (IS), as defined in the appropriate clauses of these specifications, or as otherwise specified herein. The choice of binder shall be stipulated in the contract or by the engineer. Where penetration grades of bitumen are specified, they are referred to by a single- figure designation in accordance with IS:73. Thus bitumen grade 35 refers to a bitumen in the penetration range 30 to 40. Where modified binder is specified, the Clause 521 of these specifications shall apply.

Coarse Aggregates

The coarse aggregates must consist of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. They should be clean, hard, durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious matter. Where the contractor's selected source of aggregates has poor affinity for bitumen, as a condition for the approval of that source, the bitumen must be treated with approved anti-stripping agents, as per the manufacturer's recommendations, without additional payment. Before approval of the source the aggregates shall be tested for stripping. The aggregates should satisfy the physical requirements set forth in the individual relevant clause for the material in question.

Where crushed gravel is proposed for use as aggregate, not less than 90% by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

Fine Aggregates

Fine aggregates should consist of crushed or naturally occurring material, or a combination of the two, passing 2.36 mm sieve and retained on the 75 micron sieve. They should be clean, hard, durable, dry and free from dust, soft or friable matter, organic or other deleterious matter.

The source of all materials to be used on the project must be tested and be expressly approved by the Engineer.

Source of material

The source of all materials to be used on the project must be tested and be expressly approved by the engineer. The engineer may from time to time withdraw approval of a specific source, or attach conditions to the existing approval, with adequate reason giving and recording. Any change in aggregate source for bituminous mixes, will require a new mix design, and laying trials, where the mix is based on a job mix design. Stockpiled from different sources, approved or otherwise, shall be kept separate, such that there is no contamination between one material and another. Each source submitted for approval shall contain sufficient material for at least 5 days work.

Mixing

Pre-mixed bituminous materials, including bituminous macadam, dense bituminous macadam, semi-dense bituminous concrete and bituminous concrete, shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates. Appropriate mixing temperatures can be found in Table 500-5 of these specifications; the difference in temperature between the binder and aggregate should at no time exceed 14°C. In order to ensure uniform quality of the mix and better coating of aggregates, the hot mix plant shall be calibrated from time to time. If a continuous mixing-plant is to be used for mixing the bituminous bound macadam, the contractor must demonstrate by laboratory analysis, that the cold feed combined grading is within the grading limits specified for that bituminous bound material. In the case of a designed job mix, the bitumen and filler content is to be derived using this combined grading. Further details are available in the manual for construction and supervision of bituminous works.

Transporting

Bituminous materials must be transported in clean insulated vehicles, and unless otherwise agreed by the engineer, shall be covered while in transit or awaiting tipping. Subject to the approval of the engineer, a thin coating of diesel or lubricating oil may be applied to the interior of the vehicle to prevent sticking and to facilitate discharge of the material.

Laying

Weather and seasonal limitations: laying shall be suspended while free-standing water is present on the surface to be covered, or during rain, fog and dust storms. After rain, the bituminous surface, prime or tack coat, shall be blown off with a high pressure air jet to remove excess moisture, or the surface left to dry before laying can start. Laying of bituminous mixtures shall not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/h at 2m height unless specifically approved by the engineer.

Laying shall be suspended while free-standing water is present on the surface to be covered, or during rain, fog and dust storms.

Cleaning of surface

The surface on which the bituminous work is to be laid shall be cleaned of all loose and extraneous matter by means of a mechanical broom or any other approved equipment/method as specified in the contract. The use of a high pressure air jet from a compressor to remove dust or loose matter shall be available full time on the site, unless otherwise specified in the contract.

Spreading

Except in areas where a mechanical paver cannot gain access, bituminous materials shall be spread, leveled and tamped by an approved self-propelled paving machine. As soon as possible after arrival at site, the materials shall be supplied continuously to the paver and laid without delay. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously. The travel rate of the paver, and its method of operations, shall be adjusted to ensure an even and uniform flow of bituminous material across the screed, free from dragging, tearing and segregation of the material. In areas with restricted space where a mechanical paver cannot be used, the material shall be spread, raked and leveled with suitable hand tools by experienced staff, and compacted to the approval of the engineer.

The minimum thickness of material laid in each paver pass shall be in accordance with the minimum values given in the relevant parts of these specifications. When laying binder course or wearing course approaching an expansion joint of a structure, machine laying shall stop 300mm short of the joint. The remainder of the pavement up to

Compaction of bituminous materials shall commence as soon as possible after laying

the joint, and the corresponding area beyond it, shall be laid by hand, and the joint or joint cavity shall be kept clear of surfacing material. Bituminous material, with a temperature greater than 145°C, shall not be laid or, deposited on bridge deck waterproofing systems, unless precautions against heat damage have been approved by the Engineer.

Hand placing of pre -mixed bituminous materials is to be only be permitted in the following circumstances:

(i) *F*or laying regulating courses of irregular shape and varying thickness.
(ii) *I*n confined spaces where it is impracticable for a paver to operate.
(iii) *F*or footways.
(iv) *A*t the approaches to expansion joints at bridges, viaducts or other structures.
(v) *F*or laying mastic asphalt in accordance with Clause 515.
(vi) *F*or filling of potholes.
(vii) *W*here directed by the Engineer.

Manual spreading of pre - mixed wearing course material or the addition of such material by hand-spreading to the paved area, for adjustment of level, shall only be permitted in the following circumstances:

(i) *A*t the edges of the layers of material and at gullies and manholes.
(ii) *A*t the approaches to expansion joints at bridges, viaducts or other structures.
(iii) *A*s directed by the engineer.

Cleanliness and overlaying

Bituminous material shall be kept clean and uncontaminated. The only traffic permitted to run on bituminous material to be overlaid shall be that which is engaged in laying and compacting the next course, or, where a binder course is to be sealed or surface dressed, that whic is engaged on such surface treatment. Should any bituminous material become contaminated the contractor shall make it good to the satisfaction of the engineer, in compliance with Clause 501.8.

Binder course material shall not remain uncovered by either the wearing course or surface treatment, whichever is specified in the contract, for more than three consecutive days after being laid. The engineer may extend this period, by the minimum amount of time necessary, because of weather conditions or for any other reason. If the surface of the base course is subjected to traffic, or not covered within three days, a tack coat shall be applied, as directed by the engineer.

Compaction

Bituminous materials shall be laid and compacted in layers which enable the specified thickness, surface level, regularity requirements and compaction to be achieved. Compaction of bituminous materials shall commence as soon as possible after laying. Compaction shall be substantially completed before the temperature falls below the minimum rolling temperatures stated in the relevant part of these specifications. Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this, rolling is to commence at the edges and progress towards the centre longitudinally except that on super elevated and unidirectional cambered portions, where it should progress from the lower to the upper edge parallel to the centre line of the pavement. Rolling should continue until all roller marks have been removed from the surface. All deficiencies in the surface after laying are made good by the attendants behind the paver, before initial rolling is commenced. The initial or breakdown rolling is to be done with 8-10 tonnes dead weight smooth-wheeled rollers. The intermediate rolling, is to be done with 8-10 tonnes dead weight or vibratory roller or with a pneumatic tyre roller of 12 to 15 tonnes weight having nine wheels, with a tyre pressure of at least 5.6 kg/sqcm.

Rollers should move at a speed of not more than 5 km per hour.

The finish rolling should be done with 6 to 8 tonnes smooth wheeled tandem rollers. Where compaction is to be determined by density of cores the requirements to prove the performance of rollers shall apply in order to demonstrate that the specified density can be achieved. In such cases the contractor must nominate the plant, and the method by which he intends to achieve the specified level of compaction and finish at temperatures above the minimum specified rolling temperature. Laying trials shall then demonstrate the acceptability of the plant and method used.

Bituminous materials shall be rolled in a longitudinal direction, with the driven rolls nearest the paver. The roller shall first compact material adjacent to joints and then work from the lower to the upper side of the layer, overlapping on successive passes by at least one-third of the width of the rear roll or, in the case of a pneumatic -tyre roller, at least the nominal width of 300mm. In portions with super-elevated and uni-directional camber, after the edge has been rolled, the roller shall progress from the lower to the upper edge.

Rollers should move at a speed of not more than 5 km per hour. The roller shall not be permitted to stand on pavement which has not been fully compacted, and necessary precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign matter on the pavement either when the rollers are operating or standing. The wheels of rollers shall be kept moist with water, and the spray system provided with the machine shall be in good working order, to prevent the mixture from adhering to the wheels. Only sufficient moisture to prevent adhesion between the wheels of rollers and the mixture should be used. Surplus water shall not be allowed to stand on the partially compacted pavement.

Joints

Where longitudinal joints are made in pre-mixed bituminous materials, the materials shall be fully compacted and the joint made flush in one of the following ways; only method (iii) shall be used for transverse joints:

(i) ***b***y heating the joints with an approved joint beater when the adjacent width is being laid, but without cutting back or coating with binder. The heater shall raise the temperature of the full depth of material, to within the specified range of minimum rolling temperature and maximum temperature at any stage for the material, for a width not less than 75 mm. The contractor shall have equipment available, for use in the event of a beater breakdown, to form joints by method (iii);

(ii) ***b***y using two or more pavers operating in echelon, where this is practicable, and in sufficient proximity for adjacent widths to be fully compacted by continuous rolling;

(iii) ***f***or a distance equal to the specified layer thickness, to vertical face, discarding all loosened material and coating the vertical face completely, with 80/100 penetration grade hot bitumen, or cold-applied bitumen, or polymer modified adhesive bitumen tape with a minimum thickness of 2 mm, before the adjacent width is laid. All joints shall be offset at least 300 mm from parallel joints in the layer beneath or as directed, and in a layout approved by the engineer. Joints in the wearing course shall coincide with either the lane edge or the lane marking, which ever is appropriate. Longitudinal joints shall not be situated in wheel track zones.

4.7 >> Construction process of footpath

Scope

The work shall consist of constructing footpaths and/or separators at locations as specified in the drawings or as directed by the engineer. The lines, levels and dimensions shall be as per the drawings. The scope of the work shall include provision of all drainage arrangements as shown in the drawings or as directed.

Brief Material specifications

The footpaths and separators shall be constructed with any of the following types:

(i) ***C***ast-in-situ cement concrete of Grade M20 as per Section 1700 of the Specifications.

(ii) ***P***recast cement concrete blocks/tiles of Grade M20 as per Section 1700 of the specifications. The minimum thickness of the cement concrete block/tile shall be 25 mm and minimum size shall be 300 mm x 300 mm.

(iii) ***N***atural stone slab cut and dressed from stone of good and sound quality, uniform in texture, free from defects and at least equal to a sample submitted by the contractor and approved by the engineer. The minimum thickness of the natural stone slab shall be 25 mm and minimum size shall be 300 mm x 300mm.

Technical specifications for laying concrete paving blocks used for Footpaths

IS Sieve Size	Percent Passing
9.52 mm	100
4.75 mm	95-100
2.36 mm	80-100
1.18 mm	50-95
600 micron	25-60
300 micron	10-30
150 micron	0-15
75 micron	0-10

Sieve Size	Percent Passing
2.36 mm	100
1.18 mm	90-100
600 micron	60-90
300 micron	30-60
150 micron	15-30
75 micron	0-10

The use of cement in the joint - filling sand is not recommended as a general practice as the cemented sand is likely to crack into segments which are easily dislodged.

a. Base

1.a.1 ***T***he finished surface of the concrete base shall match the design profile of the concrete blocks within ±10mm.
1.a.2 ***C***ompaction shall be done with vibratory roller. In restricted areas where normal rollers cannot operate, hand – held or plate vibrators should be employed.

b. Bedding Sand Layer

1.b.1 ***T***he bedding sand layer shall be from either a single source or blended to achieve the following grading
1.b.2 ***S***ingle sized, gap – graded sands or those containing an excessive amount of fines will not be used. The sand particles should preferably by angular type.The joint – filling sand should pass a 2.35 mm sieve and be well graded. The following grading is recommended:
1.b.3 ***A***verage thickness of this laying course shall be 20 to 40mm.
1.b.4 ***T***he sand should be slightly moist, and the moisture content shall be about 4 percent by weight.
1.b.5 ***I***t should contain not more than 3 percent by weight of clay and silt and the materials shall be free from deleterious salts or contaminates.
1.b.6 ***T***he finished surface of the bedding layer shall match exactly the design profile as indicated on the drawings.
1.b.7 ***B***efore placing the bedding layers, the surface of concrete should be clearly by sweeping.
1.b.8 ***W***alking or driving on the finished surface of the bedding layers, the surface of concrete should be cleared by sweeping.

c. Concrete Paving Blocks

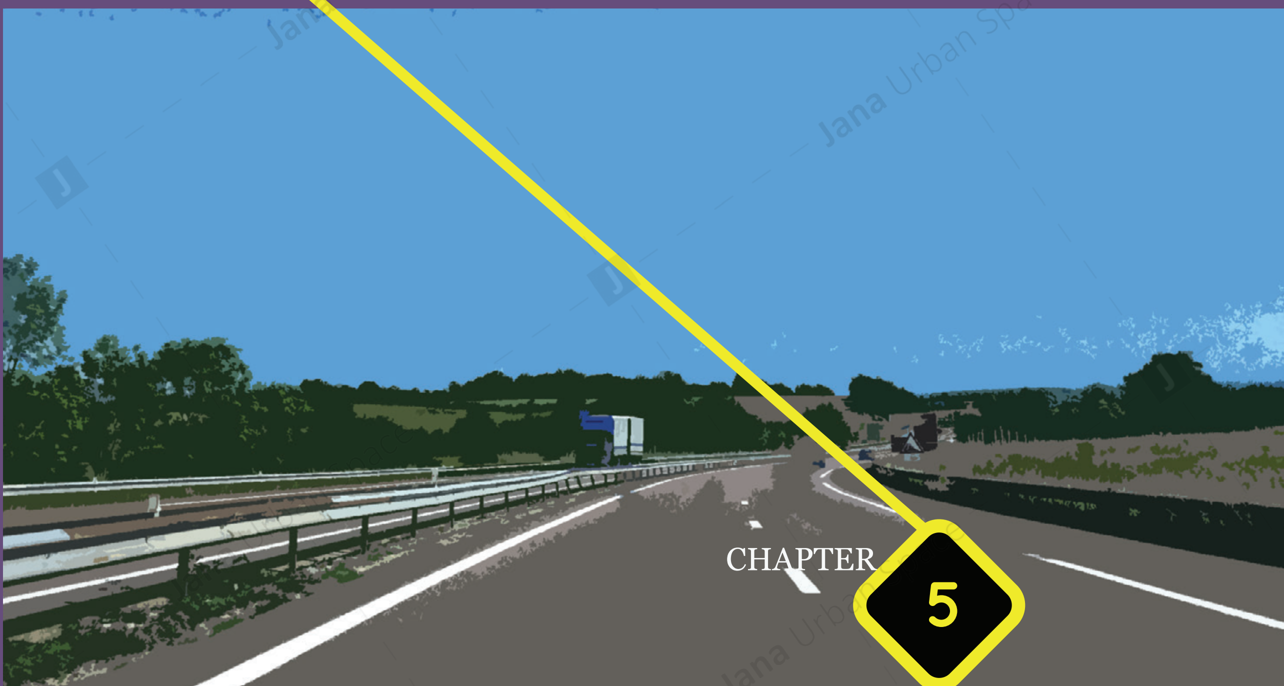
1.c.1 ***L***aying of the blocks shall be done - precisely at the indicated level and profile and in a way that a good surface draining to the gulley chambers is assured.
1.c.2 ***A***round gulley chambers and inspection pits, the pavement shall have a level of 5mm higher than the above mentioned elements.
1.c.3 ***T***he blocks shall be laid to the pattern directed by the engineer. The blocks shall be laid as tight as possible to each other. The maximum joint width shall be limited to 4mm.
1.c.4 ***L***aying of broken blocks is not allowed except along connections or edges. The maximum length of a purpose broken block is 100mm. Breaking of the blocks shall be done with a “block splitter” or a mechanical saw.
1.c.5 ***F***ine angular sand as per specification shall be brushed into the joints, and thereafter compaction shall be done with a vibrating plate compactor on a clean surface. After compaction, again fine angular

sand shall be brushed into the joints.

4.7.1 >> Plain Cement Concrete Kerb Specifications

Providing and laying of precast concrete kerbs 914 x 315 x 150mm high in M20 grade P.C.C on M-15 grade foundation using 20mm aggregates 150mm thick foundation and side support concrete laid manually as per drawings upto the required profile as per drawings including excavation, backfilling, form work,curing, including cost of all materials, labour, hire charges of machinery, loading, unloading, lead, lift, transporting etc.

Getting the drains right,
Vittal Mallya Road Bangalore



CHAPTER 5

LIFE CYCLE COSTING

tender SURE

5.0 >> Life Cycle Costing of an Urban Road (UR) System

The determination of costs is an integral part of the **Urban Road (UR)** management process.It is a common element of many of the Road Engineer's assessment tools, particularly Economic Appraisal, Financial Appraisal, Value Management, Risk Management and Demand Management.

In the past, comparisons of UR asset alternatives, whether at the concept or detailed design level, have been based mainly on initial capital costs.

Growing pressure to achieve better outcomes from UR means that ongoing operating and maintenance costs must be considered as they consume more resources over the UR's service life. Both the capital and the ongoing operating and maintenance costs must be considered wherever UR management decisions involving costs are made. This is the Life Cycle Cost approach.

Life Cycle Costing of UR is a process to determine the sum of all recurring and one-time (non-recurring) costs over the full life span or a specified period of an UR system. It includes laying cost, material cost, operating costs, maintenance, overlay and upgrade costs, and remaining (residual or salvage) value at the end of useful life of the project.

Life Cycle Costing of UR is a process to determine the sum of all recurring and one-time (non-recurring) costs over the full life span or a specified period of an UR system.

Life Cycle Costing adds all the costs of alternatives over their life period and enables an evaluation on a common basis for the period of interest. This enables decisions on acquisition, maintenance, refurbishment or disposal to be made in the light of full cost implications.

The unit cost for all 34 road types detailed in TenderSURE is estimated here based on PWD Schedule of Rates, 2010. For items that are not present in the SR book the cost is assumed by cross referencing with local engineers and similar works that has been carried out locally. The LCC calculated here should be used as a reference only as the rate analysis is factored in. Actual quantity estimates based on ground conditions such as the type of material used, grading of aggregates, quality of cement, material price escalation, detailing, aesthetics, etc. demolition, site clearance and dismantling, traffic diversion costs will influence the final costing of the projects.

Three items were considered to obtain approximate cost of laying one km of an urban road. They are ***road material composition cost, street fixtures*** and ***below grade utilities.***

To obtain approximate cost of laying one km of an urban road

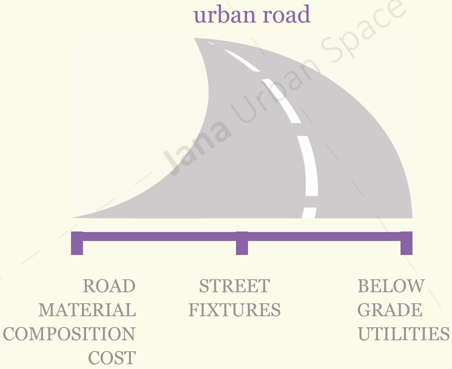


Table 5.1>>
Schedule of rates extract for local road works

Serial Number	Particulars	Cost (₹)	Unit	Reference
1	Excavation in hard soil	300	cum	Item 19.2, Pg.no 126
2	Tack coat	200	cum	Item 21.9, Pg. no 149
3	Bituminous macadam	50	cum	Item 21.11.2, Pg. no. 149
4	Semi Dense Bituminous concrete	25	cum	Item 21.20.2, Pg.no 151

Similarly, cost is calculated for higher order roads by considering all the elements.

Table 5.2>>
Schedule of rates extract for arterial, sub-arterial and collector road works

Serial Number	Particulars	Cost (₹)	Unit	Reference
1	Excavation in hard soil	72	cum	item 19.2, Pg.no 126
2	Tack coat	1,639	cum	item 20.2, Pg.no 140
3	Bituminous macadam	983	cum	item 20.18, Pg.no 143
4	Semi Dense Bituminous concrete	6,884	cum	item 21.17, Pg.no 150
5	Semi Dense Bituminous concrete	6,238	cum	item 21.20.2, Pg.no 151
6	Bituminous concrete	6,779	cum	item 21.22.2, Pg.no 152
7	UG Drain 1mx1m	2,135	running m	item 19.44, Pg.no 131
8	Footpath	415	Sq.m	item 20.21, Pg.no 144
9	UG Drain at edge of pavement	2,135	m	Item 19.44, Pg.no. 131

Life Cycle Cost (LCC) of an Urban Road

The factors affecting LCC are initial cost of construction, operation and maintenance, periodic overlay and design life of urban road. LCC is calculated for two scenarios, proposed life over 20yrs and current.

It is assumed here that when roads are built according to the integrated city plan, with well-designed right-of-ways considering various elements such as above ground fixtures and underground utilities, the post-construction operations and maintenance cost over the life of the roads. The current road construction practices require frequent maintenance cycles, among other reasons, due to imperfect methodology and excessive cutting and digging by various public and private agencies. The life-cycle cost in current practice increases significantly over the 20 year design life (see table overleaf).

Road Type	R-o-W width (M)	Tender SURE costs over 20 years	Current Costs over 20 years - conservative	Current Costs over 20 years - realistic	Cost difference Current/TenderSURE - conservative	Cost difference Current/Tender SURE - realistic
Local	10	27,846,528	30,978,000	41,304,000	111%	148%
Collector	21	102,418,536	128,785,050	171,713,400	126%	168%
Sub-arterial	30	133,717,157	176,840,100	235,786,800	132%	176%
Arterial	48	217,307,735	232,460,100	309,946,800	107%	143%

Table 5.3>>
LCC cost difference between TenderSURE and current road construction practices

Calculations for LCC of bituminous pavement road types as per Tender SURE specifications are shown in the table below. The costs are also calculated for roads as per current practices. As the preparatory work in Tender SURE roads would be according to best practices, regular O&M costs would not be high and considered at 3% whereas current roads this goes up to 5%. Even with conservative estimates of maintenance and periodic relay, 20-year LCC of roads built with current practices result in higher cumulative expenditures. In reality, the cost goes higher as relaying costs need to be calculated considering the factors such as utility shifting and upgrades etc.

Table 5.4>>
Detailed LCC cost estimates for bituminous roads as per TenderSURE and current road construction practices

	Road Type	R-o-W width (M)	Total	O & M Cost-annual (3% of initial cost) (INR)	Relay Cost - 25%of initial cost every 10yrs (INR)	Life Cycle Cost over 20 yrs (INR)
Tender SURE COST	Local	10	13,260,252	7,956,151	6,630,126	27,846,528
	Collector	21	48,770,731	29,262,439	24,385,366	102,418,536
	Sub-arterial	30	63,674,837	38,204,902	31,837,418	133,717,157
	Arterial	48	103,479,874	62,087,924	51,739,937	217,307,735

	Road Type	R-o-W width (M)	Total	O & M Cost-annual (5% of initial cost) (INR)	Relay Cost - 50%of initial cost every 4 yrs (INR)	Life Cycle Cost over 20 yrs (INR)
Current COST Conservative	Local	10	6,884,000	6,884,000	17,210,000	30,978,000
	Collector	21	28,618,900	28,618,900	71,547,250	128,785,050
	Sub-arterial	30	39,297,800	39,297,800	98,244,500	176,840,100
	Arterial	48	51,657,800	51,657,800	129,144,500	232,460,100

	Road Type	R-o-W width (M)	Total	O & M Cost-annual (5% of initial cost) (INR)	Relay Cost - 100%of initial cost every 4 yrs (INR)	Life Cycle Cost over 20 yrs (INR)
Current COST Realistic	Local	10	6,884,000	6,884,000	27,536,000	41,304,000
	Collector	21	28,618,900	28,618,900	114,475,600	171,713,400
	Sub-arterial	30	39,297,800	39,297,800	157,191,200	235,786,800
	Arterial	48	51,657,800	51,657,800	206,631,200	309,946,800

Table 5.4 (contd.)>>
Detailed LCC cost estimates for bituminous roads as per TenderSURE and current road construction practices

LCC calculations for roads with cement concrete pavement as per Tender SURE specifications are shown in the table below. As relaying is not involved in the CC roads, the 20-year LCC costs compared to bituminous roads are significantly less.

Comparative analysis with current practices cannot be done as CC roads are constructed only for narrow alleys and access roads.

	Road Type	R-o-W width (M)	Total	O & M Cost annual (2% of initial cost) (INR)	Life Cycle Cost over 20 yrs (INR)
Tender SURE COST	Local	10	14,099,490	5,639,796	19,739,286
	Collector	21	50,302,144	20,120,858	70,423,002
	Sub-arterial	30	65,545,056	26,218,022	91,763,078
	Arterial	48	107,616,172	43,046,469	150,662,641

Table 5.5>>
Detailed LCC cost estimates for cement concrete roads as per TenderSURE

Annexures

i. Mini - Circle Junction Design

1) ***P***rovision of small diameter island of a diameter of about one - third that of a hypothetical circle inscribed within the outer carriageway boundaries, but normally not less than 8m. For new layout, space for lager diameter (15m to 25m) may be reserved if such a provision becomes necessary in future.

2) ***A***n increase in number of lane at the Give - Way line.

3) ***A*** minimum stopping distance of 26m between the give way line and the point of conflict with a vehicle from the left (shown as X in the figure 1).

4) ***A*** width between traffic islands and the circle (shown as Y in the figure 1) Which is not less than the total lane width at the entry preceding it i.e. dimension shown as Z in figure 1

5) An entry taper (about 1 in 6) that is about twice sharp as the exit taper (1 in 12).

6) ***A*** deflection island (shown as B in figure 1) intends to ensure that straight- through movements do not occur.

7) ***T***o maintain junction capacity, a single lane approach should be tapered to give at least three lanes at the junction and a 2-lane approach tapered to at least four lanes at the junction. At the exit, the merge should normally be from four lanes to two lanes and two lanes to one lane.

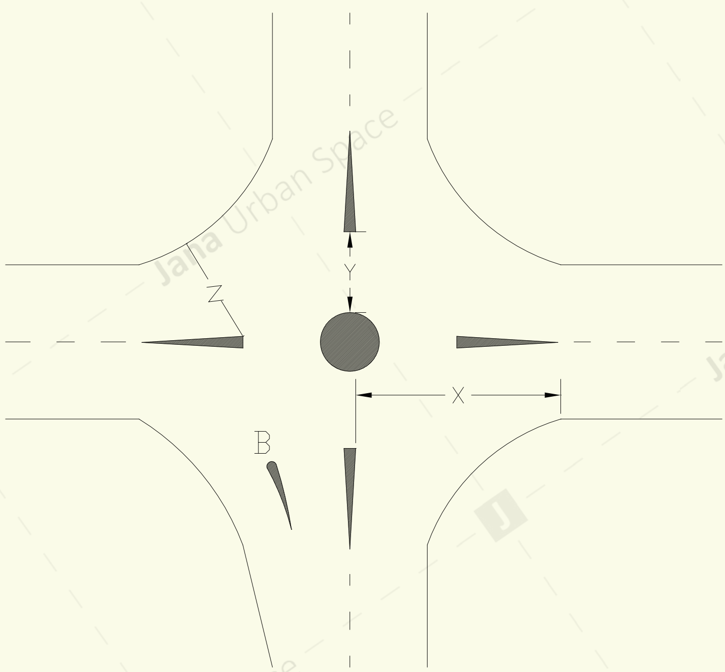


Figure 1 >>
Typical Mini - Circle

ii. Rotary Junction Design

The main of providing the rotary is to eliminate the necessity of stopping even for crossing streams of vehicles and to reduce the area of conflict.

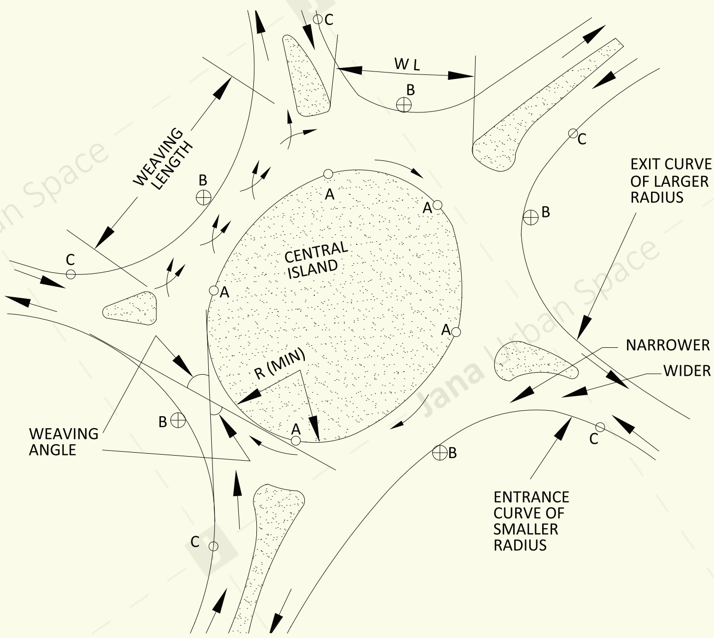


Figure 2 >>
Elements of rotary

Various design factors to be considered in a traffic rotary are speed, shape of central island, weaving angle, weaving distance, width of rotary road way, radius of entrance and exit curves, channelizing islands, lighting and signs.

Design speed – The design speed for rotaries in urban areas is 30 kmph adopted.

Shape of Central Island – The shape of Central Island depends on the number and the layout of the intersecting roads. The various shapes considered to suit condition are circular, turbine, elliptical and tangent shapes. When two equally important roads cross at roughly right angle, a circular shape is suitable.

Weaving angle – The angle between the path of a vehicle entering the rotary and that of another vehicle leaving the rotary at adjacent road, thus crossing the path of former is termed as the weaving angle, for smooth flow of traffic the weaving angle should be small but not less than 150 as the diameter of central island required will be too large.

Weaving distance – The weaving operation including merging and diverging can take place between the two channelizing island of adjacent intersecting legs and this length of the rotary roadway is known as weaving length, the recommended value of weaving length are 30 to 60m for the design speed of 30 kmph.

Width of carriageway at the entry and exit –The carriageway width at the entrance and exit of a rotary is governed by the amount of traffic entering and leaving the rotary. It is recommended that the minimum width of the carriageway be at least 5m with necessary widening to account for the curvature of the road, Table A below gives the value of the width of carriageway at entry inclusive of widening needed on account of curvature.

Table 2A >>
Value of width of carriageway

Carriageway width of the approach road	Radius at entry (m)	Width of carriageway at entry and exit (m)
7m (2 lanes)		6.5
10.5m (3 Lanes)		7
14m (4 Lanes)		8
21m (6 Lanes)	25-35	13
7m (2 lanes)		7
10.5m (3 Lanes)		7.5
14m (4 Lanes)		10
21m (6 Lanes)	15-25	15

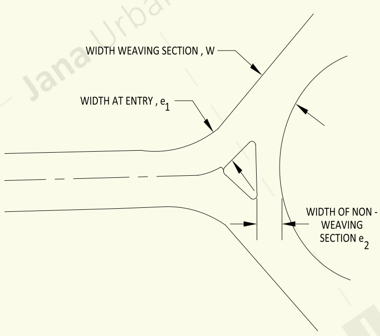


Figure 3 >>
Plan view of entry and exit of rotary

Width of rotary carriageway – The width of rotary carriageway is further split into two parts, one is the width of the weaving section and the other is the width of the non-weaving section, the weaving section width should be one traffic lane wider than the entry width and the non- weaving section width should be equal to the widest single entry into the rotary and should generally be less than the width of the weaving section.

Weaving width can be found out with the following formula
W = average of e1 and e1 + 3.5m, where W- width weaving section, e1- width at entry, e2- width of non-weaving section

Radius of curve at entry and exit –For the design speed of 30kmph the recommended radius of curve at entry is 15 to 25 m. The radius of curve at the exit should be larger than that of the central island and at the entry so as to encourage the driver to pick up speed and clear away from the rotary expeditiously. For this reason the radius of exit curve may be kept about 1.5 to 2 times the radius of entry curves

Radius of Central Island – Theoretically, the radius of central should be equal to the radius at entry. In practice, value of 1.33 times the radius of entry curve is suggested as a general guideline for adoption.

Capacity of Rotary – The practical capacity could be calculated from the following formula

$$Qp = 280\, w\, (1 + e/w)\, (1 - p/3)\, 1 + w/l$$

Qp = practical capacity of the weaving section of the rotary in passenger car unit (PCU) per hour.
W = width of weaving section in meters
e = Average entry width in meters (e/w to be within the range of 0.4 to 1.0)
l = length in meters of the weaving section between the ends of channelizing islands (w/I to be within the range of 0.12 and 0.4)
p = proportion of weaving traffic I.e. ratio of sum of crossing streams to the total traffic on the weaving section.
The range of p being 0.4 to 1.0

Traffic signage – The important traffic signages used at the rotary intersection are KEEP LEFT, NO RIGHT TURN, STOP, ROTARY AHEAD, PEDESTRIAN CROSSING, etc. the details and location all those sign boards is shown in the typical layout.

iii. Design criteria for separate cycle lane

Table 3A : Design criteria commonly adopted for cycle track

Particulars	Guidelines		
1. Justification for separate cycle tracks	where the peak cycle traffic is 400 or more on routes with vehicular traffic of 100 - 200 veh/hr. where the motor vehicle traffic is more than 200 veh/hr, a separate cycle track are justified even if the cycle traffic is only 100 per hour		
	no of lanes	one way traffic	two way traffic
	2 lanes	2000 - 5000	500 - 2000
	3 lanes	>5000	2000 - 5000
2. Capacity (per day)	4 lanes		>5000
3.Horizontal Curves (radius)	(i) Minimum 10m, (ii) where the gradient is steeper than 1 in 40, minimum radius shall be 15m.		
4.Verticle Curves	Minimum radius - submit curve - 200m and valley curve - 100m		
5. Gradients (gradient of 1 in 20 and 1 in 30 may be allowed for short lengths of 20m and 50m respectively	**Gradient**	**Maximum Length**	
	1 in 30	90	
	1 in 35	125	
	1 in40	160	
	1 in 45	200	
	1 in 50	250	
	1 in 55	300	
	1 in 60	360	
	1 in 65	425	
	1 in 70	500	
6. Sight distance	Clear view should not be less than 25m. In gradient of 1 in 40 or steeper, clear view shall not be less than 60m.		
7. Lane width	1 m per lane		
8. Width of pavement	Minimum of 2m (for 2 lanes)		
9. Clearance	(i) Vertical : 2.25 minimum and desirable 2.5m (ii) Horizontal : 0.25m		

Other general considerations for the design of separate cycle tracks are;

1. ***P***referably Cycle track should be provided on both sides of the road.
2. ***T***hey should be separated from the main carriageway be a verger or a berm, which should be preferably 0.5 to 1 m wide.
3. ***C***ycle tracks should be constructed and maintained with care and should have good riding qualities. Black – topped and concreted surface provide smooth riding qualities, whereas water bound macadam and earthen tracks are not inviting for cyclists to ride upon.
4. ***T***he tracks should be clear of obstructions such as hedges, ditches tree roots, kerbs etc. by at least 0.5m.
5. ***T***he design speed for cycles is about 32 km/hr.

iv. Patching and Repairing of Existing roads

(source: MoRTH, section 3004)

Filling Pot-holes and Patch Repairs

Scope: This work shall include repair of pot- holes and patching of all types of bituminous surfaces with a bituminous mix either produced at plant site or at the site itself with manual method of mixing and placed at site in the pot holes or in patches after trimming the pot-hole or depression to proper shape and depth, side painting with tack coat and compacting the layer to the levels specified in the drawing.

Materials : The materials used for the pot-hole and patch repair of bituminous surface shall be as per the Contract and shall be of the same type as used for the existing bituminous surface, A mix superior to the one on existing surface can also be considered appropriate for repair work. An emulsified bitumen mix compatible with the existing layer shall also be considered appropriate. The grading of aggregates and bitumen content of the mix used for such patch repair shall be in accordance with Clause 501.

Preparation of the area for pot-hole and patch repair: Each pot-hole and patch repair area shall be inspected and all loose material removed. The area shall be cut/trimmed either with jack hammer or hand tools like chisels, pick-axes etc., such that the area is in the shape of a rectangle or square. The edges shall be cut vertically upto the level where the lower layer is stable without any loose material. The area shall be thoroughly cleaned with compressed air or any appropriate method approved by the engineer to remove all dust and loose particles. The area shall be tacked or primed with cutback or emulsion depending upon whether the lower layer is bituminous or granular in nature. The sides, however, are to be painted with hoi lack coat material using a brush. The prime coat and tack coat shall conform to Clauses 502 and 503 of these Specifications, respectively.

Backfilling operation: The mix to be filled shall be either a hot mix or a cold storable mix (using bituminous emulsion). Mixing shall be done in a plant of suitable capacity. It shall be placed in thicknesses not more than 100 mm (loose). H shall be compacted in layers with roller/plate compactor/hand roller/rammer. While placing the final layer, the mix shall be spread slightly proud of the surface so that after rolling, the surface shall be flush with the adjoining surface. If the area is large, the spreading and levelling shall be done using hand shovel and wooden straight edge. During the process of compaction with roller or other means, the surface level shall be checked using a 3 m straight edge.

Measurements for payment: Filling of pot- holes and patch repair shall be measured in sq.m.

Rate: The Contract unit rate for filling of pot- holes and patch repair shall be in full compensation for:
(i) ***F***urnishing all materials required;
(ii) ***W***orks involved in trimming, tacking, palming with cutback or emulsion;
(iii) ***A***ll labor, tools, equipments and incidentals to complete the work in accordance with the Specifications.

JANAAGRAHA

PAGE 1

Work Inspection Guide (WING)

General Information

Ward Number ______________________

Locality ______________________

Name of Road/ Street/ Main/ Cross ______________________

From (door number/ site number) ____________ To (door number/ site number) ____________

Road length ____________ mts Road width ____________ mts

Inspection Of (Tick the work being inspected)

Road

- Paved Road with black top ☐
- Paved road without black top ☐
- Cement concrete road ☐
- Mud road ☐

Drain

- Side ☐
- Culvert ☐
- Shoulder ☐

Footpath

- Earth ☐
- Stone slab ☐
- Interlocked pavers ☐

Work Details (Information from ward engineers)

Name of the work ______________________

Work code ______________________

Work order number ______________________

Name of contractor ____________ Telephone Number ____________

AEE in chanrge ____________ Telephone Number ____________

Details	As per contract	Actual
Work start date		
Date of completion		
Cost of work		

Work Evaluation (as per tender and technical sanction)

As per contract specifications Yes ☐ No ☐

Signature/ Stamp of inspecting association

PAGE 2

Roads

Pot-hole/ Road cuts patching

1. Area cut into geometric shape ________
2. Area gouged out neatly ________
3. Loose material removed ________
4. Bitumen coated evenly on all surfaces and vertical edges ________
5. Aggregate compacted and level with surrounding surface ________

Metalling

1. Mix layer thickness correct and uniform (______ mm)
   - Additional 30% for compaction ________
   - Thickness specified in contract (______ mm)
2. Camber achieved (1 in 50) ________

Rolling

- Number of passes (______)
- Overlap (50%) ________
- Sequence (edge to centre) ________
- No ridges after final pass ________

Asphalting

1. Potholes and road cuts patched ________
2. Surface cleaned of loose material ________
3. Tack coat applied uniformly (spray ☐ can ☐)
4. Mix layer thickness correct (______ mm)
   - Additional 30% for compaction
5. Thickness specified in contract (20 ☐ 25 ☐ 40 ☐ mm)
6. Camber achieved (1 in 50) ________

Rolling

- Number of passes (______)
- Overlap (50%) ________
- Sequence (edge to centre) ________
- No ridges after final pass ________

Drains

Side/ Shoulder

1. De silted and cleared of debris ________
2. Broken slabs replaced ________

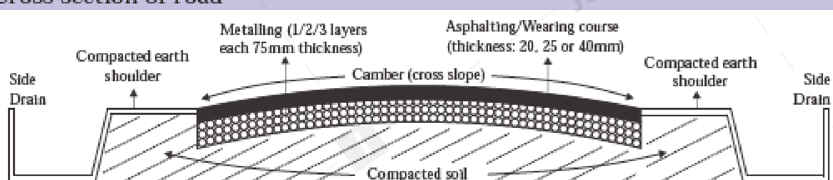
Culverts

1. De silted and cleared of debris ________
2. Broken slabs replaced ________
3. Cover slabs free of gaps ________
4. Surface level with the adjoining roads ________

Footpaths

1. Mud footpath
   - Clear vegetation ________
   - Compact earth ________
2. Stone slab footpath
   - Re-fix loose stone slabs ________
   - Surface even/ level ________
   - Replace broken stone slabs ________
   - Missing kerb-stones replaced/ re-fixed ________

Cross section of road



Has work been completed according to specification? (Yes ☐ No ☐)

v. Road Laying Checklist

(Source: Janaagraha Ward Works 2005, Prof. Justo)

SECTION I: Metalling (Base Course)

Laying Water Bound Macadam

1. Shoulder

a. ***S***houlders compacted down
b. ***K***erb stone firmly bedded (optional)

2. Standard Thickness of metalling layers after compaction

WBM grade 1: 100mm
WBM grade II: 75mm
WBM grade III: 75mm

3. Aggregate Spread

a. ***M***easure thickness during execution at edges BEFORE Compaction
b. ***L***ayer thickness 33% more than specified compacted thickness

4. Rolling

a. ***I***f dual Camber is required, the rolling should start along either edge and shift in toward the center after each lap If single camber is required rolling should start from lower edge and proceed toward higher level after each lap
b. ***R***olling runs should overlap by 50% for uniform compaction
c. ***E***ach completed compaction across the width of the road is called a pass. There should be 4- 6 such "passes" of compaction
d. ***W***alk on freshly compacted metal to test quality. It must NOT feel like walking on dry leaves

SECTION II: Asphalting

A. Preparation before overlaying or re-surfacing
1. Drainage

a. ***S***ide drains and shoulder drains must be desilted before asphalting
b. ***D***ebris to be removed within 24 hours.

2. Potholes & Ruts

a. ***A***ffected area gouged out to a rectangle/square shape (with sides vertical), down to a depth where base is stable and free of loose material
b. ***A***ll loose material and dust removed
c. (***O***nly if exposed base is non-bituminous aggregate) Prime coat of Cut-back bitumen or bituminous emulsion applied
d. ***T***ack coat of bitumen applied:
   * Either hot, or Cut-back grade, or emulsion
   * All surfaces (including the vertical edges) fully and

uniformly coated

e. ***P***re-mix bituminous material prepared and filled into the cavity and compacted

* Hot mix with well-graded aggregate of specified size and at 145 to 155 °C OR
* Cold mix of graded aggregate and bituminous emulsion OR
* Hot or cold mix with open-graded aggregate of specified size

AND

Hot or cold mix with open-graded aggregate of specified size

AND

f. ***S***eal coat applied

*Material placed in layers (50 to 100 mm thick) and each layer well compacted, till the final layer is at the same level as the adjoining area.

3. Surface cracks (upto 3mm width)

a. ***S***urface clean and dust-free

b. "***F***og Seal" applied Bituminous emulsion applied (by hand spray or pressure distributor)

* Left to cure for one hour before allowing traffic+A87

OR

"Seal Coat (Type A)" applied :

* Hot bitumen sprayed (Coverage to be uniform)

*Aggregate spread and rolled (8-IOt roller)

OR

"Seal Coat (Type B)" applied

*Hot mix of bitumen and aggregate (2.36-0.18 mm) prepared

*Mix laid (6 mm thick)

*Rolled (8-IOt roller)

4. Depression filling & Profile correction (Not necessary if max fault is less than 40 mm deep as it can be taken care of during resurfacing/ overlaying)

a. ***S***urface is free of dust

b. ***T***ack coat applied

*Applied by spray

*Coverage is uniform

c. ***B***ituminous pre-mix spread and rolled in successive layers of compacted thickness 50 to 75 mm each, till depression is totally leveled out and also correct camber (2% or 1 in 50) is achieved

5. Rectification of incorrectly filled road cuttings or trenches

i) ***T***he section below is not part of any specification, but given as expert advice (If filled material is firm and has got compacted)

a. ***M***aterial dug out to depth of 0.3m

b. ***C***avity refilled with sand (or crusher stone dust) and compacted to a thickness of 100mm
c. ***A*** layer of graded crushed hard aggregate (50 to 10 mm) size laid to a loose thickness of 100 mm, and compacted to 75 mm thickness
d. ***P***rime coat (Cut-back bitumen) applied
e. ***T***ack coat (Applied by spray and of uniform coverage)
f. ***B***M layer of compacted thickness 75 mm laid(as per Section B)
g. ***M***SS layer of compacted thickness 20 mm laid(as per Section C)

ii) If filled material is loose

a. ***M***aterial dug out to depth of 0.5m
b. ***C***avity refilled with sand (or crusher stone dust) laid in two layers and compacted to a final thickness of 180 mm
c. ***T***hree layers of graded stone aggregate (50 to 10 mm) size laid, each layer compacted to a thickness of 75 mm before spreading the next layer
d. ***P***rime coat (Cut-back bitumen) applied
e. ***T***ack coat applied by spray and uniformly
f. ***B***M layer of compacted thickness 75 mm laid (as per Section)
g. ***M***SS layer of compacted thickness 20 mm laid (as per Section)

B. Laying of Bituminous Macadam

1. Preparatory

a. ***C***omplete procedures under B, 'Preparations'
b.***D***ust and loose soil cleared

2. Bitumen coating

a. ***P***rime coat applied (Only if the existing base is non -bituminous/ granular)

*Bituminous material of low viscosity (viz. Cut-back bitumen or emulsion) sprayed
*Allowed to cure for 12 hours

b. ***T***ack coat applied

* Applied by spray and uniformly

3. Aggregate mix laying

a. ***A***ggregate size as specified
b. ***B***itumen temp (145-155 deg C)
c. ***S***pread thickness (25 to 30 % more than specified compacted thickness)

4. Rolling

a. ***R***oller weight (8 to 10 t)

Rolling sequence

*(In case of dual camber: Along edge, shifting towards center after each run, with 50% overlap. Repeat from the other edge)

OR

*(In case of single camber: Along the lower edge shifting towards higher edge after each run, with 50% overlap)

b. ***N***o. of passes (4 to 6 complete passes

c. ***N***o rolling marks to be visible during final run

d. ***R***olling completed before mix temperature falls below 100*C

5. Usage restriction

a. ***R***oad not to be opened for traffic unless cooled down to ambient temperature and a surfacing course (BC or MSS or PC or at least Seal coat) has been applied

C. Laying of Pre-mix Carpet (PC) or Mixed Seal Surfacing (MSS) (4.1 and 4.2 required only if PC/MSS is being laid on old existing black top surface and not on freshly constructed BM / DBM surface)

1. ***S***urface preparation
    a. ***C***omplete procedures as per section B
2. ***B***itumen (Tack) coat
    a. ***A***pplied by spray and with uniform coverage
    b. ***B***itumen/Aggregate layer
    c. ***A***ggregate sizes (22.4-11.2 mm & 13.2-5.6 mm for PC ; Various for MSS)
    d. ***B***itumen temp (145-155*C)
    e. ***B***itumen uniformly coated
    f. ***S***pread thickness (27 mm) compacted to 20 mm
3. ***R***olling
    a. ***A***s per C.4
    b. ***R***olling must be started before mix temperature comes down to 120°C and completed before it falls below 100°C
    c. ***F***inal layer thickness should be average 20 mm(Check within a few hours of completion
4. ***S***eal Coat

(Only required on PC layer and is to be applied before cooling down) (Type A)

a. ***B***itumen sprayed to seal off all voids on the surface

b. ***A***ggregate (11.2 to 2.6mm) spread immediately and rolled (Type B)

c. ***C***oarse sand (2.36 to 0.18) pre-mixed with bitumen spread and rolled immediately

5. ***S*urface Finish Checks**

a. ***W***hen water is poured, make sure it flows either along the slope of the road or across the width of the road

b. ***W***hen water is poured on the surface of the road, absorb-tion of a very small proportion of about 5% is acceptable.

c. ***L***ongitudinal undulations causing uncomfortable ride in a small car or scooter is not acceptable

d. ***C***amber (At least 2%, or I in 50)

SECTION III : Bituminous Concrete

1. ***C*omplete all procedures under asphalting**

2. ***T*ack Coat application**

Applied by spray [not perforated can]

3. ***A*ggregate Mix Laying**

a. ***A***ggregate size as specified (Checked by sieves)

b. ***B***itumen mix temp (145-155°C)

c. ***S***pread thickness (25% more than specified compacted thickness)

4. ***R*olling**

As per section II-C

5. ***S*urface Finish Checks**

a. ***W***hen water is poured, make sure it flows either along the slope ofthe road or across the width of the road

b. ***W***hen water is poured on the surface of the road, absorp tion of a very small proportion, of about 5% is acceptable.

c. ***L***ongitudinal undulations causing uncomfortable ride in a small car or scooter is not acceptable

d. ***C***amber (At least 2%, or 1 in 50)

vi. Material Testing Specifications

Sl. No	Type of Construction	Test	Frequency (min)
1	Granular	(i) Gradation (ii) Atterberg limits (iii) Moisture content prior to compaction (iv) Density of compacted layer (v) Deleterious constituents (vi) C.B.R.	One test per 200 m3 One test per 200 m3 One test per 250m3 One test per 500 m3 As required As required
2	Lime/Cement Stabilised Soil Sub-base	(i) Quality of lime/cement (ii) Lime/Cement content (iii) Degree of pulverization (iv) CBR or Unconfined Compressive Strength test on a set of 3 specimens (v) Moisture content prior to compaction (vi) Density of compacted layer (vii) Deleterious constituents	One test for each consignment subject to a minimum of one test per 5 tonnes Regularly, through procedural checks Periodically as considered necessary As required One test per 250 sq. m. One test per 500 m2 As required
3	Water Bound Macadam	(i) Aggregate Impact Value (ii) Grading (iii) Flakiness Index and Elongation Index (iv) Atterberg limits of binding material (v) Alterberg limits of portion of aggregate passing 425 micron sieve	One test per 200 m3 of aggregate One test per 100 m3 One test per 200 m3 of aggregate One test per 25 m3 of binding material One test per 100 cubic metre of aggregate
4	Wet Mix Macadam	(i) Aggregate Impact Value (ii) Grading (iii) Flakiness and Elongation Index (iv) Atterberg limits of portion of aggregate passing 425 micron sieve (v) Density of compacted layer.	One test per 200 m3 of aggregate One test per 100m3 of aggregate One test per 200 m3 of aggregate One test per 100m3 of aggregate One test per 500 m2

6A.Control tests and their minimum frequency for subbases and bases (excluding bitumen bound bases) (source: MoRTH - table 900-3)

ANNEXURE 6 MATERIAL TESTING SPECIFICATIONS

Sl. No	Type of Construction	Test	Frequency (min)
1	Prime Coat/Tack Coat	(i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by the Engineer
		(ii) Binder temperature for application	At regular close intervals
		(iii) Rate 'of spread of Binder	Two tests per day
2	Seal Coat/Surface Dressing	(i) Quality of binder	Two samples per lot Dressing to be subjected to all or some tests as directed by the Engineer
		(ii) Aggregate Impact Value	One test per 50m5 of aggregate
		(iii) Flakiness Index and Elongation Index	One test per 50m5 of aggregate
		(iv) Stripping value of " aggregates	Initially one set of 3 representative specimens for each "source of supply. Subsequently when warranted by changes in the quality of aggregates
		v) Water absorption of aggregates	Initially one set of 3 representative specimens for each "source of supply. Subsequently when warranted by changes in the quality of aggregates
		(vi) Grading of aggregates	One test per 25 m3 of aggregate
		(vii) Stone polishing value	As required
		(viii) Temperature of binder at application	At regular close intervals
		(ix) Rate of spread of materials	One test per 500 m1 of work
3	Open-graded Premix Carpet/Mix-Seal Surfacing	(i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by Engineer
		(ii) Aggregate Impact Value	One test per 50 ms of aggregate
		(iii) Flakiness Index and Elongation Index of aggregates	-do-
		(iv) Stripping value	Same as mentioned under Serial No, 2
		(v) Water absorption of aggregates	Same as mentioned under Serial No, 2
		(vi) Grading of aggregates	One test per 25 m1 of aggregates
		(vii) Stone polishing value	As required
		(viii) Temperature of binder at application	At regular close intervals
		(ix) Binder content	Two tests per day
		(x) Rate of spread of mixed material	Regular control through checks on materials and layer thickness
4	Bituminous Macadam	(i) Quality of binder	Two samples per lot to be subjected to all or some tests as directed by the Engineer
		(ii) Aggregate Impact Value	One lest per 50 m3 of aggregate
		(iii) Flakiness Index and Elongation Index of aggregates	-do-
		(iv) Stripping value	Same as mentioned under Serial No. 2
		(v) Grading of aggregates	Two tests per day per plant both on the individual constituents and mixed aggregates from the dryer
		(vi) Water absorption of aggregates	Same as in Serial No. 2
		(vii) Binder content	Periodic, subject to minimum of two tests per day per plant
		(viii) Control of temperature of binder and aggregate for mixing and of the mix at the time of laying and rolling	At regular close intervals
		(ix) Rate of spread of mixed material	Regular control through checks of layer thickness
5	Bituminous Penetration Macadam/ Built-up Spray-Grout	(i) Quality of binder	Two samples per lot to be subjected to alt or some tests as directed by the Engineer.
		(ii) Aggregate Impact Value	One test per 200m! of aggregate
		(iii) Flakiness Index and Elongation Index	-do-
		(iv) Stripping value	Same as mentioned under Serial No 2
		(v) Water absorption of aggregates	Same as in Serial No. 2
		(vi) Aggregate grading	One test per 100 m! of aggregate
		(vii) Temperature of binder at application	At regular close intervals
		(viii) Rate of spread of binder	One test per 500 m2 of area

6B.Control tests and their minimum frequency for subbases and bases (excluding bitumen bound bases)
(source: MoRTH - table 900-3)

Sl. No	Type of Construction	Test	Frequency (min)
6	Dense Bituminous Macadam/Semi Dense Bituminous Concrete/ Bituminous Concrete	(i) Quality of binder	Two samples per lot lo be subjected lo all or some tests as directed by the Engineer
		(ii) Aggregate Impact Value	One test pet 50 m1 of aggregate
		(iii) Flakiness Index and Elongation Index of aggregates	--do-
		(iv) Stripping Value	As in Serial No. 2
		(v) Water absorption of aggregates	As in Serial No. 2
		(vi) Sand equivalent test	As required
		(vii) Stone Polishing Value	As required for Semi Dense Bituminous Concrete / Bituminous Concrete
		(viii) Mix grading	One set of tests on individual constituents and mixed aggregate from the dryer for each 400 tonnes of mix subject ID a minimum of two tests per plant per day
		(ix) Stability of Mix	For each 400 tonnes of mix produced, a set of 3 Marshall specimens to be prepared and tested for stability, flow value, density and void content subject to a minimum of two sets being vested per plant per day
		(x) Water sensitivity of mix (Retention of Marshall Stability)	As required for Bituminous Concrete
		(xi) Swell lest on the mix	-do-
		(xii) Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling	At regular close intervals
		(xiii) Control of binder content and gradation in the mix	One test for each 400 tonnes of mix subject to a minimum of two tests per day per plant
		(xiv) Rate of spread of mixed material	Regular control and through checks on the weight of mixed material and layer thickness
		(xv) Density of compacted layer	One lest per 250 m1 area

ANNEXURE 6 MATERIAL TESTING SPECIFICATIONS

Sl. No	Type of Construction	Test	IS codes	Frequency (min)
1	Cement	Physical and chemical tests	IS ; 269 IS : 455 IS : 14S9 IS : 8112 IS : 12269	Once for each source of supply and occasionally when called for in case of long/improper storage, Besides, the Contractor also will submit daily data on cement released by the Manufacturer
2	Coarse and Fine aggregates	(i) Gradation	IS : 2386 (Pt 1)	One use test for every day's work of each fraction of coarse aggregate and fine aggregate, initially; may be relaxed later at the discretion of the Engineer.
		(ii) Deleterious constituents	IS : 2386 (Pt. 2)	-do-
		(iii) Water absorption	IS:2386 (Pt. 3)	Regularly as required subject to a minimum of one lest a day for coarse aggregate & two tests a day for fine aggregate. This data shall be used for correcting the water demand of the mix on daily basis.
3	Coarse aggregates	(i) Los Angeles Abrasion value or Aggregate Impact lest	IS:2386 (Pt. 4)	Once for each source of supply and subsequently on monthly basis.
		(ii) Soundness	IS:23S6 (Pt.5)	Before approving the aggregates and every month subsequently
		(iii) Alkali aggregate reactivity	IS:2386 (Pt. 7)	do-
4	Water	Chemical Tests	IS:456	Once for approval of source of supply, subsequently only in case of doubt,
5	Concrete	(i) Strength of concrete	IS:516	2 cubes and 2 beams per 150 in' or part thereof (one for 7day and other for 28 day strength) or minimum 6 cubes and 6 beams per day's work whichever is more.
		(ii) Core strength on hardened concrete	IS:516	As per the requirement of the Engineer; only in case of doubt.
		iii) Workability of fresh concrete-Slump Test	IS:1199	One lest per each dumper load at both Batching plant site and paving site initially when work starts. Subsequently sampling may be done from alternate dumper.
		(iv) Thickness determination		From the level data of concrete pavement surface and sub-base at grid points of S/ 6.25 m x 3.5 m
		(v) Thickness measurement for trial length		3 cores per trial length.
		(vi) Verification of level of string line in the case of slip form paving and steel forms in the case of fixed form paving		String line or steel forms shall be checked for level at an interval of 5.0m or 6.25 m. The level tolerance allowed shall be ± 2mm. These shall be got approved 1-2 hours before the commencement of the concreting activity.

6C. Frequency of quality control tests for paving quality concrete (source: MoRTH - table 900-6)

v11. Flexible Pavement Design (extracted from JnNURM Rapid Training Programme – Preparation of DPRs, CEPT Ahmedabad)

Design Approach & Criteria

Carriage of the road can mostly be design by the following three layer structure

1. ***B***ituminous surface layer(s)
2. ***G***ranular Base
3. ***G***ranular Sub base

This structure rests on sub-grade which in turn rests on natural ground.

Design of Flexible Pavement

The following sub sections describe the various variables and parameters involved in design of flexible pavement of road as per IRC 37 - 2001.

Traffic- CV/Day Annual traffic census 24 X 7

For structural design, commercial vehicles are considered. Thus vehicle of gross weight more than 8 tonnes load are considered in design. This is arrived at from classified volume count.

Wheel loads

Urban traffic is heterogeneous. There is a wide spectrum of axle loads plying on these roads. For design purpose it is simplified in terms of cumulative number of standard axle (8160 kg) to be carried by the pavement during the design life. This is expressed in terms of million standard axles or msa.

Climate

Temperature is an important factor affecting the performance of flexible pavement (Hot or Cold). Most of our country comes under hot climate. In urban scenario, the traffic is heterogeneous. There is sizable bicycle traffic. There is sizable pedestrian traffic. The demand for road can be estimated by a classified volume count of traffic. This survey should be conducted for seven days throughout – 24 x 7 surveys. All vehicle categories including non motorised traffic like bicycles, animal driven carts etc. There should be a separate pedestrian survey. An Origin – Destination (OD) survey to estimate preference for a particular route may also be carried out. Locations attracting heavy traffic demand such as Government offices, commercial centres, hospitals, educational institutes, religious and other places of interest may be marked and traffic generated should be estimated.

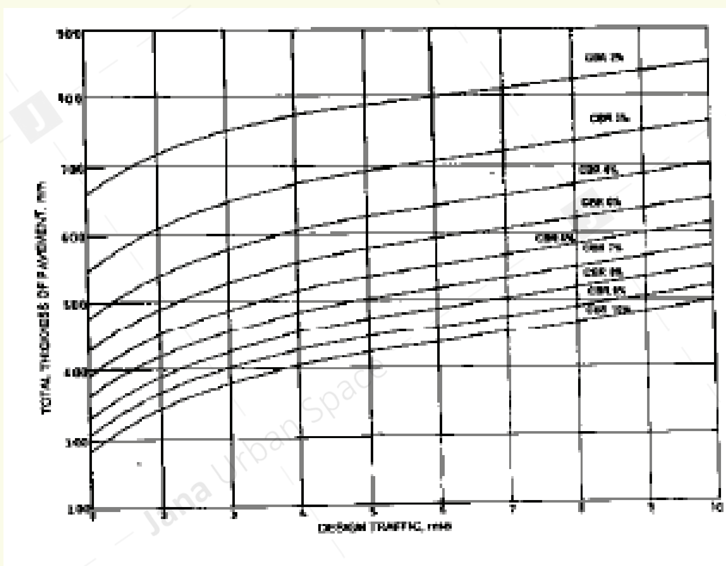
A detailed socio economic study is required for understanding and future trends. Planning must provide for future requirements. It is usually found that the future projections are overtaken by faster developments, people start development faster than estimated years the grade of bitumen to be used in surface layers. Planning must provide for future requirements. Considerations for different climate are given in annexure 6 of IRC 37 – 2001.

Terrain Plain or Hilly

The terrain is dependent on natural gradient available. When natural gradient is up to 10 percent, it is known as plain terrain. When natural gradient is between 10 to 25 percent, terrain is known as rolling. When natural gradient is between 25 to 60 percent, terrain is known as hilly. And when natural gradient is more than 60 percent, terrain is known as steep terrain.

Pavement Thickness

Pavement Thickness Composition can be decided by using following chart presented in figure 10A.



10 A. Pavement thickness Design Chart for Traffic1 1-10 msa

Design Traffic

Computation of design Traffic In terms of cumulative number of standard axle to be carried by the pavement during design life.

$$n = \frac{\{365 \times ((1+r)^{n} - 1)\}}{r} \times A \times D \times F$$

Where,
N = The cumulative number of standard axles to be catered for in design in terms of million standard axles - msa.
A = Initial traffic in the year of completion of construction duly modified as shown below. D = Lane distribution factor
F = Vehicle damage factor, VDF
n = Design life in years
r = Annual growth rate of commercial vehicles

Design factors

A = P (1 + r)

Where,
P = Number of commercial vehicle as per last count
X = Number of years between the year of last count and the year of completion of construction
D = Lane distribution factor

It is the distribution of commercial traffic over the carriageway. It should be considered by deciding the lane of the road. Following values should be taken for lane distribution factor.

Table 10.1 .
Road Sections
(Source: IRC 37)

Description	Lane Distribution Factor (D)
Single Lane Road	1.00
Two Lane Single Carriageway	0.75
Two Lane Double Carriageway	0.40
Four Lane single Carriageway	0.40
Four Lane Double Carriageway	0.45

F = Vehicle damage factor (VDF).

It is a multiplier to convert the number of CV of different axle load and axle configuration to the number of standard axle load repetition. VDF depends on vehicle configuration, axle load, terrain, type of road. Where sufficient information of axle load is not available then the VDF value considered are presented in table 10.2.

Table 10.2 .
Vehicle Damage
Factor (Source: IRC 37)

Initial Traffic volume in terms of Commercial Vehicles per Day	Terrain	
	Rolling / Plain	Hilly
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

In view of the concept of cumulative axle loads, it is now possible to design a flexible pavement for a definite period.

Design Period

A design period of 15-20 years should be adopted for arterials sub-arterial and 10-15 years should be adopted for local and Collector Street. A higher design should be taken for small towns and lower period for large cities. For high volume streets and busy intersections, peak hour volumes should be used to determine the width of road.

For Arterial & Sub arterial 15-20 years
For collector & local road 10-15 years
Expressway and Urban Roads - 20 Years
N H & SH – 15 Years
Other Roads – 10 – 15 Years

r - Traffic Growth: From the data's available for the last five or ten years traffic census traffic growth can be determined. In absence of adequate data, an average value of 7.5 % per annum growth rate may be adopted.

CBR Value
California Bearing Ratio (CBR) Value as per IS 2720 (Part-XVI):

- CBR is an indirect measure of the stability of sub-grade i. e. the capacity to resist deformations under wheel loads.
- CBR value is determined by conducting the CBR test on specimen in laboratory as per the procedure laid down in IS 2720 Part- XVI
- It is basically a penetration test.
- The CBR test is carried out in standard CBR apparatus & the standard test procedure prescribed in accordance with IS 2720(part-XVI) as per the requirement.
- The material is statically compacted in three layers at MDD & OMC determined by a standard proctor test as per IS 2720 –part:7 for light compaction or IS-2720- part:8 for heavy compaction as per the requirement.
- The sample is subjected to 4 days soaking.
- There after a plunger of 50 mm dia. is allowed to penetrate in the material at the rate of 1.25 mm/min.
- The required loads required causing 2.5 mm & 5.0 mm penetrations are recorded.
- These loads are then expressed as percentages of standard/loads, which are the loads for corresponding penetrations in standard crushed stone aggregates.
- Higher of two values is adopted as CBR value.

As per the IS requirements three samples shall have to be tested for CBR and the average CBR value of three samples is taken as final CBR provided the CBR value of all three samples are within the permissible limit of variation.

CBR (Percent)	Maximum Variation in CBR Values
5	±1
5-10	±2
10-30	±3
31 and above	±5

Table 10.3 . pavement thickness design chart for traffic 1-10 MSA (source: irc 37; 1998)

Table2.7: Recommended Design for Traffic range 1-10 msa 1

msa for given CBR Value	Total Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Base Course	Sub base Course
		Wearing Course (mm)	Binder Course (mm)		
CBR 3 %					
1	550	20 PC		225	435
2	610	20 PC	50 BM	225	335
3	645	20 PC	60 BM	250	335
5	690	25 SDBC	60 DBM	250	335
10	760	40 BC	90 DBM	250	380
CBR 2%					
1	660	20 PC		225	435
2	715	20 PC	50 BM	225	440
3	750	20 PC	60 BM	250	440
5	795	25 SDBC	70 DBM	250	450
10	850	40 BC	100 DBM	250	460
CBR 4%					
1	480	20 PC		225	255
2	540	20 PC	50 BM	225	265
3	580	20 PC	50 BM	250	280
5	620	25 SDBC	60 DBM	250	285
10	700	40 BC	80 DBM	250	330
CBR 5%					
1	430	20 PC		225	205
2	490	20 PC	50 BM	225	215
3	530	20 PC	50 BM	250	230
5	580	25 SDBC	55 DBM	250	250
10	660	40 BC	70 DBM	250	300
CBR 6%					
1	390	20 PC		225	165
2	450	20 PC	50 BM	225	175
3	490	20 PC	50 BM	250	190
5	535	25 SDBC	50 DBM	250	210
10	615	40 BC	65 DBM	250	260
CBR 7%					
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	460	20 PC	50 BM	250	160
5	505	25 SDBC	50 DBM	250	180
10	580	40 BC	60 DBM	250	230
CBR 8%					

Source: IRC 37; 1998

msa for given CBR Value	Total Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Base Course	Sub base Course
		Wearing Course (mm)	Binder Course (mm)		
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	450	20 PC	50 BM	250	150
5	475	25 SDBC	50 DBM	250	150
10	550	40 BC	60 DBM	250	200
CBR 9 % & 10 %					
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	450	20 PC	50 BM	250	150
5	475	25 SDBC	50 DBM	250	150
10	540	40 BC	50 DBM	250	200

Source: IRC 37; 1998

Fig 10B : pavement thickness design chart for traffic 10-150 msa

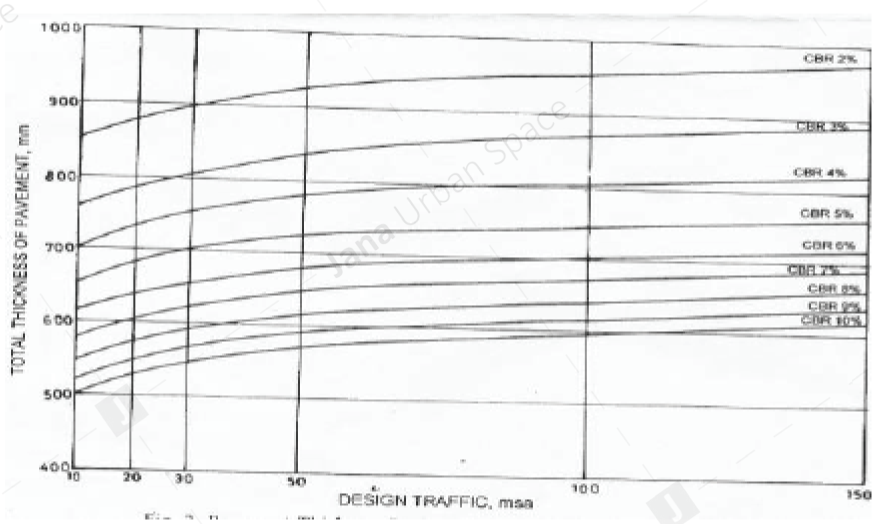


Table 2.8: Recommended Design for Traffic range 10 – 150 msa

msa for given CBR Value	Total Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		
		BC (mm)	DBM (mm)	
CBR 2%				
10	850	40	100	Base = 250
20	880	40	130	
30	900	40	150	
50	925	40	175	Sub base = 460
100	955	50	195	
150	975	50	215	
CBR 3%				
10	760	40	90	Base = 250 Sub base = 380
20	790	40	120	
30	810	40	140	
50	830	40	160	
100	860	50	180	
150	890	50	210	
CBR 4%				
10	700	40	80	Base = 250 Sub base = 330
20	730	40	110	
30	750	40	130	
50	780	40	160	
100	800	50	170	
150	820	50	190	
CBR 5%				
10	660	40	70	Base = 250 Sub base = 300
20	690	40	100	
30	710	40	120	
50	730	40	140	
100	750	50	150	
150	770	50	170	
CBR 6 %				
10	615	40	65	Base = 250 Sub base = 260
20	640	40	90	
30	655	40	105	
50	675	40	125	
100	700	50	140	
150	720	50	160	
CBR 7 %				
10	580	40	60	Base = 250 Sub base = 230
20	610	40	90	
30	630	40	110	
50	650	40	130	
100	675	50	145	
150	695	50	165	
CBR 8 %				
10	550	40	60	Base = 250 Sub base = 200
20	575	40	85	
30	590	40	100	
50	610	40	120	

msa for given CBR Value	Total Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		
		BC (mm)	DBM (mm)	
100	640	50	140	
150	660	50	160	
CBR 9 %				
10	540	40	50	Base = 250 Sub base = 200
20	570	40	80	
30	585	40	95	
50	605	40	115	
100	635	50	135	
150	655	50	155	
CBR 10 %				
10	540	40	50	Base = 250 Sub base = 200
20	565	40	75	
30	580	40	90	
50	600	40	110	
100	630	50	130	
150	650	50	150	

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Glossary

GLOSSARY

Aggregate	Stone and gravel of various sizes which compose the major portion of the surfacing material. The sand or pebbles added to cement in making concrete.
Aggregate Base Course	The layer of material laid immediately beneath the pavement. It may be composed of crushed stone, crushed or uncrushed sand and gravel, or combinations of these materials. To provide the service intended it must be uniform in strength to support the pavement.
Alignment	The vertical and horizontal location of a road.
Arbitrator	A private, neutral person chosen to arbitrate a disagreement, as opposed to a court of law. An arbitrator could be used to settle any non-criminal dispute, and many business contracts make provisions for an arbitrator in the event of a disagreement. Generally, resolving adisagreement through an arbitrator is substantially less expensive than resolving it through a court of law.
Arbitration	A process in which a disagreement between two or more parties is resolved by impartial individuals, called arbitrators, in order to avoid costly and lengthy litigation.
Auxiliary Lane	Auxiliary lanes are added at the intersection, usually to accommodate turning motor vehicle
Average Daily Traffic or ADT	A measurement of the number of vehicle which use a highway over a period of a year divided by 365 to obtain the average for a 24-hour period.
Backfill	Material used to replace, or the act of replacing, material removed during construction. Also, may denote material placed, or the act of placing material adjacent to structures.
Base	A course of fairly rigid material, sometimes cement- or asphalt-treated, that is placed on the sub¬-base to provide a stable platform for the concrete pavement slab.
Bid	Bid means the documents in their entirety comprised in the bid submitted by the Bidder in response to the Tender Notice in accordance with the provisions thereof.
Bicycle Lanes	Portions of a roadway set aside for bicycle use, with the lanes distinguished from the motor vehicle portion of the roadway by painted stripes, curbs, or parking blocks.
Bitumen	A natural asphalt or substance found in a natural state or a residue by-product from petroleum refinement.

GLOSSARY

Bituminous Containing Bitumen

Borrow Pit The source of approved material required for the construction of embankments, or other portions of earthwork requirements.

BRT Bus rapid transit (BRT) is a term applied to a variety of public transportationsystems using buses to provide faster, more efficient service than an ordinary bus line.

Capacity Maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway in one direction during a given time period under prevailing roadway and traffic conditions.

Cement A powdered product made by grinding clinkers of limestone, clay, and other materials, and which reacts with water to form a rock like substance used to bond aggregates together in concrete.

Chevron marking A Chevron is an inverted V-shaped or V-shaped pattern used as warning sign to guide motorists on the approach to islands/ostructions within the travel lane.

Chicane A chicane is an artificial feature creating extra turns in a roadway, used in motor racing and on city streets to slow cars.

Concrete Concrete is a building material made of sand and gravel bonded together with portland cement into a hard, compact substance.

Corridor An area of variable width between two points. In highway work, corridors are defined areas where the needs for Improvements are studied.

Cross fall The transverse sloping of a travel lane toward the verge or gutter on either side

Cul-de-sac Local street open at one end only, which allows vehicles to turn around.

Culvert Any structure, not classified as a bridge, which provides an opening under the roadway.

Cutting A trenchlike excavation, especially through a road section.

Dead End A local street open at one end only and with no special provisions for turning around.

Design Capacity Maximum number of vehicles which can pass over a lane or roadway during one hour without operating conditions falling below a preselected design level.

GLOSSARY

Design Life Initially figured to be a 20-year period for pavement.

Design Phase The development of a project from the conclusion of the corridor location work to the completion of final plans.

Design Speed A speed determined for design and correlation of the physical features of a highway which influence vehicle operation.

Design Standards Specifications for such design features as curvature, grades, roadway width, drainage facilities, etc.

Destination The zone in which a trip ends.

Divided Highway A roadway with separated roadways for traffic in opposite directions.

Earth Excavation On a construction project that requires new or relocated roadway, the earth which must be moved from one place to another is called earth excavation.

Egress The exit points on a controlled access roadway.

Emulsified Asphalt An emulsified asphalt is a common construction material used to prime, seal or resurface a highway. It consists of an asphalt that is chemically mixed with water in an emulsion.

Excavation The act of taking out materials, the materials taken out, or the cavity remaining after materials have been removed.

Expressway A divided arterial road for through traffic with full or partial control of access and generally with grade separations at major intersections.

Filling Something that is put in to fill something else.

Fly ash A byproduct of coal furnaces. When mixed with soil and water, it acts as a binder. Self-cementing Class C fly ash can be used for treating sub-grades.

Forecasting Procedure for estimating future land use, population and traffic patterns.

Functional Classification Identification of a road by the function it serves.

Grade Separation A crossing of two arterial roads, or a arterial road and a railroad, at different levels. The bridge that spans highways or Rail road tracks (as in an overpass) is a grade separation structure.

Guard Rail A steel rail with two corrugations at the shoulder edge of a highway, usually in front of roadside hazards. Also cable guard rail.

GLOSSARY

Highway, Street or Road	A general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.
Horizontal Curve	Bend from a straight line or course along a roadway.
Ingress	The entrance points on a roadway which have access control.
Interchange	A system of interconnecting roadways providing for the free movement of traffic between two or more roadways on different levels.
Intermodal Transfer	Change from one type of carrier to another.
Internal Trip	A trip with both origin and destination within the survey area.
Land Use	The functions for which various land areas are used or are planned to be used, such as: agriculture, housing, education, cultural recreations, religious, industrial and commercial uses.
Level of Service	The term used to indicate the quality of service provided by a facility under a given set of operating conditions. These conditions include speed, travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating costs.
Lime	Either quicklime or hydrated lime, either high calcium or dolomitic. Through chemical reactions with soil, lime reduces soil plasticity and increases com¬pressive strength. It is sometimes used to stabilize wet soils.
Maintenance	The preserving and keeping of each type of roadway, roadside, structure, and facility as nearly as possible in its original condition as constructed, or as later improved.
Maintenance and Operating Costs	Cost of keeping the road in operating condition.
Median	The portion of a divided highway separating the traveled ways for traffic in opposite directions.
Modal Split	The division of person trips between mass and private transportation.
Mode of Travel	Means of travel such as auto driver, vehicle passenger, mass transit passenger, or pedestrian.
Mulch	A protective covering spread on the ground to reduce evaporation, maintain even soil temperature, and prevent erosion.
Neighborhood	A primary informal group consisting of all persons who live in local proximity.

GLOSSARY

Node	A specific point on a study system network where two or more links intersect and where a choice of travel routing is possible.
Noise	Unwanted sound.
Noise Level	The degree of undesired sound which affects the auditory senses.
Operating Speed	The highest overall speed at which a driver can travel on a given roadway under favorable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis.
Origin	The zone in which a trip begins.
Origin-Destination Studies	Trip data is obtained from vehicle drivers as to where they started, where they are going, and the purpose of their trip. This data helps the Department to forecast traffic patterns.
Over-All Speed	Total distance divided by total time, including all delays.
Overpass	A grade separation where the highway passes over a highway or railroad.
Parking Lane	An auxiliary lane primarily for the parking of vehicles.
Pavement	The part of a roadway having a constructed surface for the facilitation of vehicular movement.
Pavement Marking	The lane lines or symbols painted on pavement surfaces. Marking can be done with several different types of materials.
Pavement/ Pothole Patching	When the pavement begins to deteriorate due to the influences of the environment and traffic, holes, ruts and cracks are usually localized at existing pavement joints. The repair of this type of failure consists of sawing out, removing and replacing the material with new Portland cement concrete or bituminous concrete.
PCU's	Passenger Car Equivalent is essentially the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car.
Peak Hour	That one-hour period during which the maximum amount of travel occurs. Generally, there is a morning peak and an afternoon peak and traffic assignments may be made for each period, if desired.
Pedestrian	Any person afoot.

GLOSSARY

Pedestrian Crossings	Designated crossings where pedestrians may safely cross a busy highway or roadway.
Population Estimate	Estimating current population on the basis of demographic and economic data.
Population Forecast	Estimating future population on the basis of demographic and economic data.
Portland cement	Hydrates with moisture in the soil and hardens. Portland cement performs best with well graded, sandy, and gravelly materials with 10 to 35 percent fines. More cement is usually needed for soils with little or no fines and with clay soils.
Public, Mass or Rapid Transit	(a) Vehicles used to convey people from one place to another. (b) The system or company which owns such vehicles.
Raised Island	That portion of the roadway which is raised above the travel-way by means of a curb to separate traffic.
Ramp	A connecting roadway between two intersecting highways at a highway separation.
Right-of-Way	Land acquired by purchase, gift or eminent domain in order to build and maintain a public road.
Roadside Development	Those items necessary to complete the highway which provide for the preservation of landscape materials and features; the rehabilitation and protection against erosion of all areas disturbed by construction through seeding, sodding, mulching and the placing of other ground covers, trees and shrubs, and such suitable planting and other improvements as may increase the effectiveness and enhance the appearance of the highway.
Scheduling	The process of developing a plan of operations to carry out the program. The process first involves breaking down projects into activities, setting starting and ending times for those activities, determining the resources required to perform the work, then adjusting the times as necessary to balance the resource requirements.
Service lane	A local road that runs parallel to an expressway or interstate highway and that provides access to the property bordering it. Also called frontage road.
Shoulder	The portion of the roadway adjacent to the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of the base and surface courses.

Sight Distance The line of sight available to the driver to see another car for passing sight distance or to see a fixed object for stopping sight distance

Social Costs Cost that is not included in the usual calculations concerning engineering, construction and right-of-way costs.

Socio-Economic Factors These are used to assess the effect of the highway on the human environment. Some include: population trends and growth, economic activity, transportation facilities, wildlife, scenic and wildlife, scenic and recreational facilities, historical resources, aesthetics, social service facilities, land use, and national defense.

Soil Erosion The wearing away of soil by the action of water, wind, or glacial ice.

Specifications The standard specifications, supplemental specifications, special provisions, and all written or printed agreements and instructions pertaining to the method and manner of performing the work or to the quantities and qualities of the materials to be furnished under the contract.

Speed-change Lane An auxiliary lane including tapered areas, primarily for the acceleration or deceleration of vehicles entering or leaving the through traffic lanes.

Sub-base A course of material that is placed on the subgrade to provide drainage and stability. Three kinds of sub-bases may be used, based on the need to balance drain ability and stability:

>> Granular subbase is the most drainable subbase. It is a mixture of granular material that is uniformly shaped and minimally compacted. It does not provide sig¬nificant structural support; no construction traffic is allowed on a granular subbase.

>> Modified subbase is moderately drainable. It contains a greater percentage of crushed particles and a denser gradation than granular subbase, providing more sta¬bility.

>> Special backfill provides more stability and support but is the least drainable. It is generally a uniform mixture of crushed concrete or crushed limestone, or a mixture of gravel, sand, and soil, with or without crushed stone. Special backfill or modified subbase is often used under pavement in urban areas to support construction traffic.

Sub-grade Earth that has been graded to the desired elevation. (In villages and municipal paving projects with low traffic volumes, concrete is often placed directly on the prepared earth subgrade.)

Surfacing Material used to construct the roadway. There are four types: Asphalt, Bituminous, Concrete, Gravel.

GLOSSARY

Tender — A formal offer made for supply of goods or services in response to an invitation for tender published in a Tender Bulletin. There are three types of tender, they are as follows:

- >> *Open tender – which is open to all bidders*
- >> *Restricted tender – which is open only for the pre-qualified bidders*
- >> *Short term tender – duration of the tenders can be reduced based on the requirements*

Tender Document — The set of papers detailing the requirement of goods Procurement Process and services, calendar of events, schedule of works, technical specifications, procurement criteria and such other particulars as may be prescribed for evaluation and comparison of tenders.

Topography — Representation on maps or charts depicting natural and man-made features of an area or region.

Topographical Survey — To gather survey data about the natural and man-made features of the land, as well as its elevations.

Traffic — All types of conveyances, together with their load, whether singly or as a whole, as well as pedestrians, while using any roadway for the purpose of transportation or travel.

Traffic Assignment — A method of distributing trips on a road network or on a theoretical network to illustrate how various sets of physical conditions and travel characteristics would affect the traffic flow pattern, for instance, speed, distances, etc.

Traffic Control Device — Any sign, signal, marking or installation placed or erected under public authority, for the purpose of regulating, warning, informing or guiding traffic.

Traffic Count — A count of total vehicular traffic passing a given point on a roadway during a specified time period. This might be a manual or machine count.

Traffic Demands — The number of vehicles desiring to use a particular route.

Traffic Flow — The movement of vehicles on a roadway system or on a single route.

Traffic Forecasting — Estimating future traffic patterns on the basis of known transportation variables.

Traffic Island — An island provided in a roadway to separate or direct streams of traffic; includes both divisional andchannelizing islands.

GLOSSARY

Travel lane	A strip delineated on a street or highway to accommodate a single line of vehicles.
Traffic Marking	A traffic control device consisting of line, patterns, or colors on the pavement, curbs, or other objects within or adjacent to the roadway, or words or symbols on the pavement.
Traffic Sign	A traffic control device mounted on a fixed or portable support which conveys a specific message by means of words or symbols, and is officially erected for the purpose of regulating, warning, or guiding traffic.
Traffic Signal	A power-operated traffic control device by which traffic is regulated, warned, or alternately directed to take specific actions.
Traffic Volume	The amount of traffic on a particular route.
Travel Time	The time of travel, including stops and delays, except those off the traveled way.
Traffic Islands	The traffic is separated to flow through definite paths by raising a portion of the roadin the middle usually called as island.
Trench less cabling	Trechless cabling or plowing technology, also known as cable plow or mole plow technology, which cuts across the road without digging the road and cables are burried.
Trip	A one-direction movement of a vehicle which begins at the origin at the start time, ends at the destination at the arrival time, and conducted for a specific purpose.
Trip Generation	Commonly used to describe the number of trips starting or ending in a particular area in relation to the land use or socio-economic characteristics of that area.
Turning Radius	At intersection turning radius are important for vehicle's maneuvering or making turns, if there is no sufficient turning radius, sometimes a big vehicle can occupy more space blocking the intersection, hence the turning radius for the speed 15 to 30km per hour should be minimum of 15mtr to 27mtr respectively for arterial and sub arterial road, for local road (residential road) were only car, two wheelers and small vehicle are plying the radius can be minimum of 7mtr.