PROJECT MANAGEMENT CONSULTANCY FOR IMPLEMENTATION OF SMART CITY MISSION PROJECTS FOR MANGALURU CITY

SMART ROAD PACKAGE - 05

DETAILED PROJECT REPORT - VOLUME I

The purpose of the Detailed Project Report is to provide details of various considerations made towards the elements proposed for the project as mentioned in the title above. It aims to give a basic design idea to all the stakeholders before proceeding for final design and estimates.

MANGALORE SMART CITY PROJECT

Lalbaug, M.G. Road, Mangalore – 575003

4/23/2019

ISSUE AND REVISION RECORD

Revision	Date	Originator	Checker	Approver	Description	Standard
1	23/04/2019	WTESL/LBI/ CDAC	MANI NARAYAN	URVI BHATT/ KAVITA WAKADE	DETAILED PROJECT REPORT	

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ABBREVIATIONS

ABD	Area Based Development
ATM	Automated Teller Machine
MCC	Mangaluru City Corporation
MSCL	Mangaluru Smart City Limited
GoI	Government of India
GoK	Government of Karnataka
SCP	Smart City Proposal
SPV	Special Purpose Vehicle
IRC	Indian Road Congress
IUT	Institute of Urban Transport
KUIDFC	Karnataka Urban Infrastructure Development & Finance Corporation Limited
SCP	Smart City Proposal
SLNA	State Level Nodal Agency
ROW	Right of Way
MESCOM	Mangalore Electricity Supply Company Limited
KSRTC	Karnataka State Road Transport Corporation
LED	Light Emitting Diode
CCTV	Closed-circuit Television
GCP	Ground Control Points
DTM	Digital Terrain Model
LCV	Light Commercial Vehicle
ADT	Average Daily Traffic
PCU	Passenger Car Units
MoUD	Ministry of Urban Development
IT	Information Technology
ICT	Information and Communication Technology
ITS	Intelligent Transport System
ITMS	Intelligent Traffic Management System
OFC	Optical Fiber Cable
O&M	Operation and Maintenance
DPR	Detailed Project Report
RFP	Request for Proposal

SOR	Schedule of Rates
PWD	Public Works Department
RTO	Regional Transport Office

LIST OF REFERENCE CODES, STANDARDS, AND GUIDELINES

The following Codes and Standards have been referred in preparing the document

1. Indian Roads Congress (IRC) Codes & Standards
   - IRC: 86-1983 - Geometric Design Standards for Urban Roads in Plains
   - IRC: 106-1990 - Guidelines for Capacity of Urban Roads in Plain Areas
   - IRC: 58-2015 - Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Fourth Revision)
   - IRC: 15-2017 - Code of Practice for Construction of Jointed Plain Concrete Pavements (Fifth Revision)
   - IRC: SP:23-1983 - Vertical Curves for Highways
   - IRC: 65-2017 - Guidelines for Planning and Design of Roundabouts (First Revision)
   - IRC: 69-1977 - Space Standards for Roads in Urban Areas
   - IRC: 99-2018 - Guidelines for Traffic Calming Measures in Urban and Rural Areas (First Revision)
   - IRC: 103-2012 - Guidelines for Pedestrian Facilities
   - IRC: SP:12-2015 - Guidelines for Parking Facilities in Urban Roads
   - IRC: SP:41-1994 - Guidelines on Design of At-Grade Intersections in Rural & Urban Areas
   - IRC: 35-2015 - Code of Practice for Road Markings
   - IRC: 67-2012 - Code of Practice for Road Signs

2. Documents prepared by Institute of Urban Transport, Ministry of Urban Development
   - Code of Practice Part I – Cross Section
   - Code of Practice Part II – Intersections
   - Code of Practice Part III – Road Marking
   - Code of Practice Part IV – Signage
   - Code of Practice Part V – Traffic Calming

EXECUTIVE SUMMARY

A) INTRODUCTION OF SMART CITIES MISSION

The Smart City Mission aims at driving economic growth and improving the quality of life of the people by enabling local government and harnessing technology as a means to create smart outcomes for citizens.

The focus is on achieving sustainable and inclusive development in compact arrears and to replicate their success in other aspiring cities

The program strategizes to undertake implementation through area based development approach through Retrofitting (City Improvement), Redevelopment (City Renewal), Greenfield Development (City Extension) and Pan City Initiatives

B) BACKGROUND OF MANGALURU CITY

Mangalore, officially known as Mangaluru, is the chief port city of the Indian state of Karnataka located about 352 km west of the state capital, Bangalore. It is the second major city in Karnataka state in all aspects after the capital city Bangalore. It is the only city in Karnataka to have all modes of transport — Air, Road, Rail and Sea along with 5 other major cities in India and is also known as the Gateway of Karnataka. It is the largest city in the Tulu Nadu region of Karnataka. Mangalore is the second best business destination in Karnataka after Bangalore & 13th best in India. The population of the urban agglomeration was 623,841, according to the provisional results of the 2011 national census of India.

Mangalore is one of the major portsin India which handles 75 per cent of India's coffee and cashew exports. Mangalore is the largest city and administrative headquarters of the Dakshina Kannada district, and is one of the most multicultural non-metro cities of India. The city's landscape is characterised by rolling hills, coconut palms, freshwater streams and hard red-clay tiled-roof buildings.

Mangalore is also included in the Smart Cities Mission list and one among the 100 smart cities to be developed in India. The city has an average elevation of 22 m (72 ft) above mean sea level. Mangalore has a tropical monsoon climate, and is under the influence of the Southwest monsoon.

C) DESCRIPTION OF ABD REGION

Mangaluru Smart City Proposals (SCP) is considered as Area Based Development Proposals (ABD) and Pan City Proposals. The SCP has identified 65 projects/sub projects to be taken up under ABD and Pan City Proposal. Figure 1-1 shows the ABD area considered under Mangaluru Smart City Proposal and the priority roads for development as smart roads

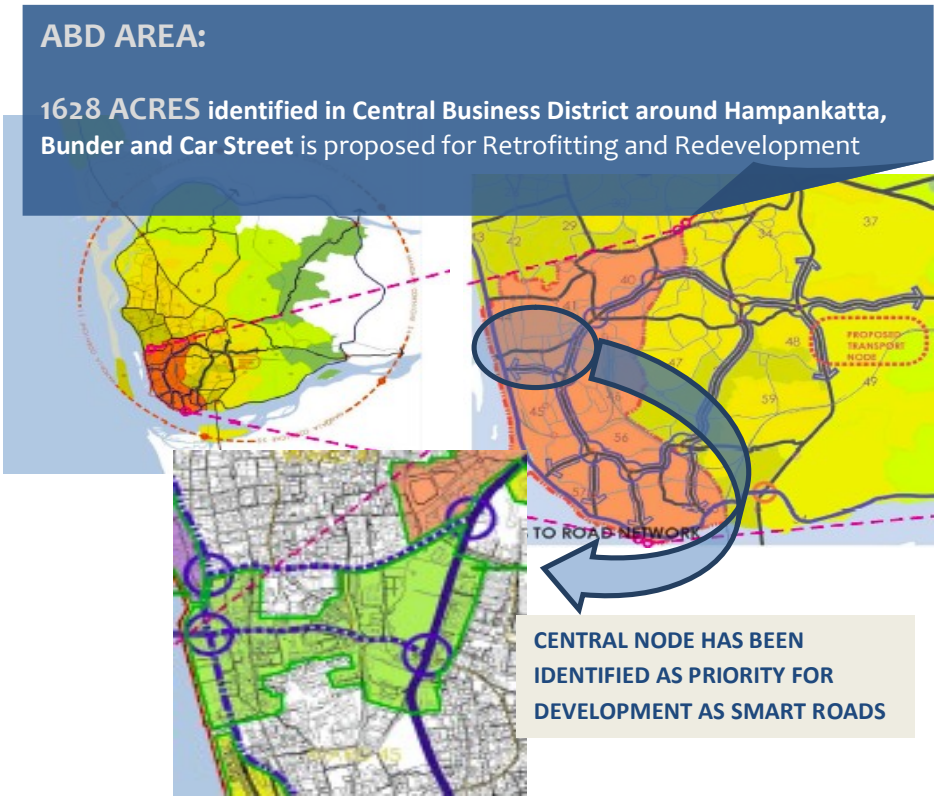


Figure 1 ABD area considered under Mangaluru Smart City and Priority Roads Identified for Development as Smart roads

D) PROPOSED PROJECTS IN SCP

Sr. No.	Name of the Project	Value of the Project (in INR Cr)
1	Improvements to Nehru Maidan Road from Clock Tower to AB Shetty Circle	7.560
2	Development of MLCP with retail space near Hampankatta Junction	94.000
3	Construction of Under Ground Drainage in zone-4 (Part-1) in ABD area Package -01	4.995
4	100% Underground Drainage network in ABD Area - Package 3	3.000
5	Conversion of all the lighting in government building into LED	2.230
6	Installation of Rooftop Solar on Government Buildings in ABD area - Phase 1	7.080
7	Implementation of Command and Control Center Components	38.790
8	Construction of Smart Bus shelter and E-Toilets in PAN City - Phase 1	4.800
9	Construction of Smart Bus shelter and E-Toilets in PAN City - Phase 2	4.600
10	Construction of Under Ground Drainage in Zone IV part 2 and Zone III part 1 in ABD Area Package -02	9.500
11	Redevelopment of Central Market along with Fish Market	145.000
12	LED Street Lights	69.350
13	Smart Road Package 2	12.500
14	Smart Road Package 3	42.060

15	Smart Road Package 4	48.000
16	Smart Road Package 5	49.000
17	Smart Road Package 6	48.000
18	Smart Road Package 7	40.520
19	Smart Road Package 9 – Pedestrian Plaza Underpass near Clock Tower Circle	5.310
20	100% water supply coverage along with residential meters, water quality monitoring and SCADA	10.000
21	Implementation of rain water harvesting in all building having area more than 1000 sqft.	2.000
22	100% Underground Drainage network in ABD Area - Package 4	25.200
23	100% Underground Drainage network in ABD Area - Package 5	49.000
24	100% Underground Drainage network in ABD Area - Package 6	46.010
25	Retrofit Car Street & areas of Sri Venkatramana Temple as Religious Zone	14.590
26	Redevelopment of Vacant Premises of DC office into Hotel, Retail Shops and Speciality Restaurants	10.000
27	Upgradation of Wenlock & Lady Goshen Hospital- Package 1	8.040
28	Skill Development and Safety Training Centre	3.300
29	Implementation of E-smart schools in all government schools - Package 1 - Infrastructure	11.000
30	Implementation of E-smart schools in all government schools - Package 2 – ICT	5.000
31	Waterfront Area Development- Package 1	49.000
32	Waterfront Area Development- Package 2	49.000
33	Waterfront Area Development- Package 3	49.000
34	Waterfront Area Development- Package 4	48.000
35	Waterfront Area Development- Package 5	40.000
36	Retrofitting of tile and Brick factories into Hotel, Auditorium, Convention Centre, Museum, Marina with retail and Speciality Restaurants- Package 1	6.000
37	Retrofitting of tile and Brick factories into Hotel, Auditorium, Convention Centre, Museum, Marina with retail and Speciality Restaurants- Package 2	8.000
38	Retrofitting of tile and Brick factories into Hotel, Auditorium, Convention Centre, Museum, Marina with retail and Speciality Restaurants- Package 3	10.050
39	Development of Green Area along Connector Road	7.020
40	Solar and Recreational Island	86.740
41	Installation of Roof Top Solar on Government Buildings - Package 2	10.000
42	Installation of Roof Top Solar on Government Buildings - Package 3	10.000
43	IPDS Proposals - Package 1	15.000
44	IPDS Proposals - Package 2	15.000
45	Redevelopment of Old Bus Stand Area	25.000
46	Construction of Command and Control Center Building	3.000
47	Command and Control Center - Stage 2	49.000
48	Command and Control Center - Stage 3	23.690
49	Construction of Smart Bus shelter and E-Toilets in PAN City - Phase 3	3.560
Total Project Cost		**1327.495**

Table 1 Smart City Project Details

E) SMART ROAD PROJECT WITHIN ABD

Transforming existing roads into Smart Roads has been envisaged under the Smart City Mission. In this regard, Mangaluru Smart City Ltd (MSCL) intends to develop world class road infrastructure that is efficient mode of transport and inclusive to all strata of society. This entails comprehensive upgrading of the public Right of Way (ROW) of the streets which includes refurbishment of existing carriageway, laying of new footpaths and cycle tracks, creating utility corridors, developing pedestrian facilities, development works for landscape, hardscape, street furniture, signage, lighting, etc.

The following projects proposed under Mangaluru SCP have been clubbed together and considered under Design and Development of Smart Roads.

As per sanctioned SCP earlier, the projects combined to be taken for smart roads package 3 are listed below:

SMART ROADS	Specialized Pedestrian Facilities along certain road sections	S NO. 19	ABD COMPONENT
	Widening of Roads	S NO. 21	ABD COMPONENT
	Upgradation of Roads with footpaths	S NO. 23	ABD COMPONENT
	Provision of Road side plantation	S NO. 25	ABD COMPONENT

p
e
r

As per the revised SCP, sanctioned recently the smart road Packages are listed below:

Sr. No.	Name of the Project	Value of the Project (in INR Cr)
1	Improvements to Nehru Maidan Road from Clock Tower to AB Shetty Circle	7.560
2	Smart Road Package 2	12.500
3	Smart Road Package 3	42.060
4	Smart Road Package 4	48.000
5	Smart Road Package 5	49.000
6	Smart Road Package 6	48.000
7	Smart Road Package 7	40.520

Table 2 Smart Road Packages

Smart Roads under Mangaluru Smart City

The development of smart roads has been perceived in phased manner:

Package 1 included Maidan road (from Clock Tower Circle to AB Shetty Circle

Package 2 included Maidan road II (from AB Shetty Circle to Hamilton Circle), 4th Cross road, Mission Street Road and Nellikai road.

Package 3 included Balmatta road (two way), Balmatta road (one way), Light house hill road, Rosario Church road, Pandeshwar road and Bunder road.

Package 4 included the following roads:

1. **Mother Theresa Road: Hampankatta to Milagres cross road**
2. **Attavar Road : Mother Theresa road to Nandigudda road**
3. **Sturrock Road : Avery Junction –Anand Shetty Circle**
4. **Bunts Hostel road: Jyoti Circle to Bunts hostel junction**
5. **KudmalRanga Rao Road part A: Arya Samaj Road Junction to PVS Circle**
6. **KudmalRanga Rao Road part B: PVS Circle to Hampankatta junction**

Package -05 Road Details are tabulated below:

1. **Milagres Cross Road (KMC Marcara Road – Mother Theresa Road Junction)**
2. **Nandigudda Attavara Road (Wenlock Railway Node – Attavara KMC Hospital Jn.)**
3. **New Balmatta Road (Jyothi Circle – Avery Junction)**
4. **Don Bosco School Road (KMC Marcara – Avery Junction)**
5. **Azizuddin Road (Lower Car Street – Bunder Police Station)**
6. **Jumma Masjid Road (Lower Car Street – Bombay Lucky Junction)**
7. **Arya Samaj Road (Arya Samaj KRR Rd Jn – Collector's Gate Circle)**
8. **Balmatta Road (Jyothi Circle – Collector's Gate Circle)**
9. **Bengre Ferry Road (Port Rd Ansari Rd Jn – BMS Ferry Line)**

Table 3 Package -05 Road Details

Other Roads to be developed in future phase(s) include Mangaladevi Road, Car Street (from Sri Venkatramana Temple to Tile Factory), Bibi Alabi Road (from Junction with Nellikai Road to Bengre Ferry), Bunder Road (from Junction with Old Port Road to Hoige Bazaar), Marnamikatta Road. Junction Improvements are considered as integral part of smart roads design and development. Figure below shows the Roads considered for development as Smart Roads for DPR 1, 2, 3, 4, 5, 6A, 6B & 7.

Phase	Rd. no.	Name of Rd.	From	To	Road Length
I - Pilot	1	**Nehru Maidan Rd.**	AB Shetty Circle	Clock Tower	545.00
II - Loop Rd	1	**Maidan Rd.-II**	AB Shetty Circle	Hamilton Circle	248.00
II - Loop Rd	2	**4th Cross Rd.**	Hamilton Circle	Rao & Rao Circle	266.00
II - Loop Rd	4	**Nellikai Rd.**	Hamilton Circle	Missn. St - Nellikai Jn	352.00
II - Loop Rd	3	**Mission St. Rd**	Misn. St-Nellikai Jn	Rao & Rao Circle	206.00
III	1	**Rosario Church Rd.**	Hamilton Circle	Bunder Railway Gate	898.81
III	2	**Pandeshwar Rd.**	AB Shetty Circle	Rosario Church Rd.	479.96
III	3	**Bunder Police Station**	Bombay Lucky Jn.	Railway Gate Bus Stop	1336.57
III	4	**KMC Mercara Trunk**	Hampankatta Jn.	Jyoti circle	984.24

		Rd.			
III	5	**Light house hill Rd.**	Hampankatta Jn.	Jyoti circle	961.14
III	6	**Mohd. Ali Rd.**	Nellikai Jn.	Bombay Lucky Jn.	100.00
IV	1	**Balmatta Rd.**	Clock Tower	Hampankatta	365.32
IV	2	**Mother Theresa Rd.**	Hampankatta Jn.	Milagres Church Jn.	224.06
IV	3	**Milagres Nandigudda Rd.**	Milagres Church	Nandigudda Rd.	322.96
IV	4	**KSR Rao Rd.**	PVS Circle- KSR Rd.	Hampankatta Jn.	1123.23
IV	5	**KRR Rd. (Kudmal Ranga Rao Rd.)**	PVS Jn.	Arya Samaj Rd. Jn.	1118.88
IV	6	**Bunts Hostel Rd.**	Bunts Hostel Jn.	Jyothi Circle	961.14
V	1	**Milagres Cross Rd.**	KMC Central Library Jn	Milagres Church Jn	183.00
V	2	**Attavara-Nandigudda Rd.**	Nandigudda Wenlock Jn	KMC Hospital	1021.00
V	3	**Kudumbi Garden (DBS) Road**	KMC Mercara Trunk Rd.	Avery Juction	375.00
V	4	**New Balmatta Rd.**	Jyoti circle	Avery Juction	577.00
V	5	**Arya Samaj Rd.**	KRR Rd - Arya Samaj Rd Jn.	Balmatta Road Jn.	595.00
V	6	**Balmatta Road**	Jyoti circle	Arya Samaj Road Jn.	330.00
V	7	**Azizuddin Road**	Car Street	Bunder Police Station	717.00
V	8	**Jumma Masjid-Old Port Rd.**	Car Street	Badria School Jn.	966.00
V	9	**Bendre Ferry Rd.**	Jumma Masjid	BMS Ferry Lane	1103.00
VI	1	**OLD PORT ROAD**	Hamilton Circle	Bendre Ferry - Old Fort Jn	465.00
VI	2	**OLD KENT ROAD**	Old Kent Rd.	Mangaladaevi Rd Jn.	820.00
VI	3	**PANDESHWARA NEW ROAD**	Rosario Church Rd.	Pandeshwar New Rd.	280.00
VI	4	**BOLAR FISHERIES COLLEGE RD**	Hoigebazar Rd. (KFDC Ltd)	Sea Face (Mangaluru Old Port)	150.00
VI	5	**MULIHITHLU ROAD**	Mangaladevi Temple	Mulihithlu Rd.	920.00
VI	6	**MANGALADEVI TEMPLE ROAD**	Mangaladevi Temple	Marnamikatta Circle	830.00
VI	7	**MONKEYSTAND NEW ROAD**	Mangaladevi Rd (Ramakrishna Math Jn)	Jaihind Circle	539.01
VI	8	**JEPPU MARKET ROAD**	Abhaya Limbs Center	Jeppu Market Jn.	225.00
VI	9	**GUJJARKERE ROAD**	Jeppu Market Jn.	Jappina Mogaru	645.00
VII	1	**G.H.S ROAD (Footpath Only)**	Balmatta Road	Sharavu Temple Jn	370.00
VII	2	**P.M RAO ROAD**	KSR Road	GHS Road Jn (Srinivas College)	145.00

VII	3	**SHARAVU TEMPLE ROAD**	KSR Road	GHS Road Jn (Ganapathi Mandir)	185.00
VII	4	**G.H.S CROSS ROAD (Jewellery Ln)**	GHS Road Jn	Flower Market Rd	180.00
VII	5	**VITOBHA TEMPLE ROAD**	KSR Road (Karnataka Bank)	Venkataramana Temple Sq.	490.00
VII	6	**MAIDAN 1st CROSS ROAD**	Mangala College (via Central Market Rd)	Car Street Cross Rd.	375.00
VII	7	**CENTRAL MARKET BACK SIDE RD**	Clock Tower Circle	Market Road Jn	150.00
VII	8	**MAIDAN 3rd CROSS ROAD**	Bibi Alabi Rd	Bibi Alabi Rd-Kandak Rd Jn	180.00
VII	9	**BIBI ALABI ROAD**	Clock Tower Circle	Rao & Rao Circle	470.00
VII	10	**BIBI ALABI - KANDAK ROAD**	Central Market Parking	MPT Road Jn	460.00
VII	11	**MAIDAN 4TH CROSS ROAD - EXTN**	Rao & Rao Circle	Kandak Road Jn	195.00
VII	12	**MPT ROAD**	Car Street (Viswakarma Bank)	Mohd Ali Road Jn	715.00
VII	13	**KASSAIGALLI MASJID SIDE ROAD**	Kassaigalli Masjid	JM Road	200.00
VII	14	**J.M 1st CROSS ROAD**	Ramachandra Mandir	Jumma Masjid Rd	235.00
VII	15	**MISSION STREET ROAD - EXTN**	Mission Street Azizuddin Jn	Bendre Ferry Rd	245.00
VIII	1	**ARYA SAMAJ RD - KADRI JN**	KRR Rd - Arya Samaj Rd Jn.	Kadri Jn	881.77
VIII	2	**COLLECTORS GATE - PUMPWELL**	Collector's Gate Jn	Pumpwell Jn	1459.36
VIII	3	**FALNIR RD (AVERY - KANKANADY)**	Avery Jn	Kankanady Jn	1207.23
VIII	4	**S.L MATHIAS ROAD**	Sturrock Road Jn	Bendoor Well Jn (MT Road Jn)	976.38
VIII	5	**ATTAVARA KATTE ROAD**	KMC Hospital	Kotichennaya Jn	811.01
VIII	6	**MPHASIS ROAD**	Marnamikatte Jn	Jeppu Market Jn.	545.23
VIII	7	**JEPPU MORGANS GATE ROAD**	Jeppu Market Jn.	Mphasis Jn	334.34
VIII	8	**DONGERKERY ROAD**	Navbharat Circle	Chitra Jn	721.19
SP1	1	**Car Street Road**	Chitra Jn	Lower Car Street	797.92
SP1	2	**Connector Road**	Yemmekere Jn	Bolar Sea Face	934.88
SP1	3	**Mahakali Padpu Road**	Mphasis Jn	Jeppina Mogaru Jn	926.02

Table 4 Mangaluru Smart City: Smart Roads Packages

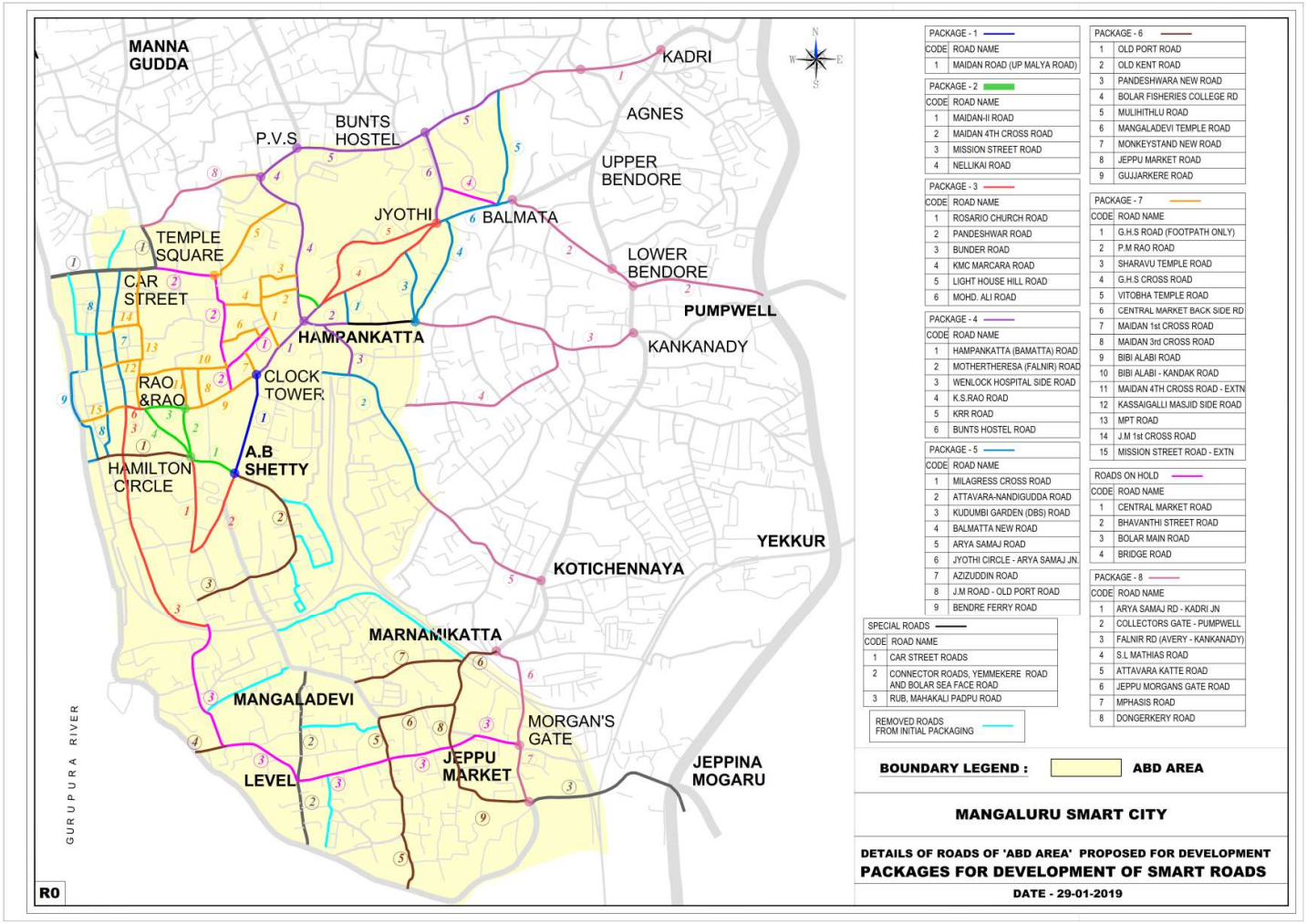
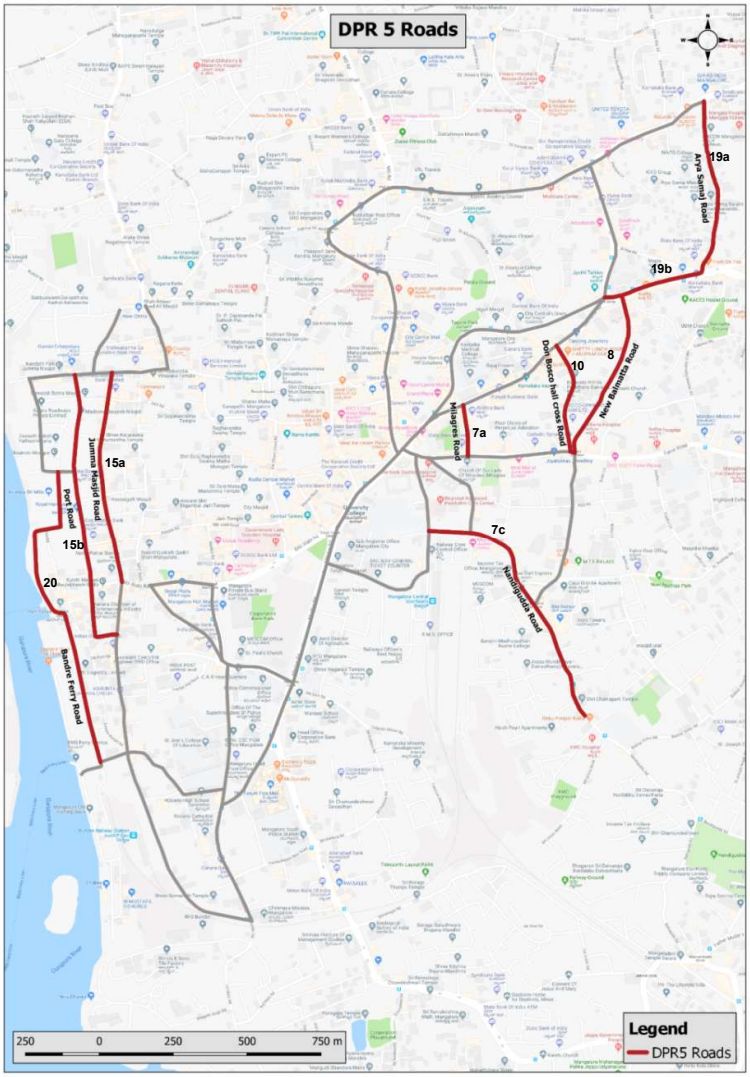


Figure 2 Selected Roads to be developed as smart roads

F) SELECTED ROADS IN THE PRESENT DPR (Package – 05)

The present DPR consist detailed working of 9 number of roads namely

7a	Milagres Cross Road (KMC Marcara Road – Mother Theresa Road Junction)
7c	Nandigudda Attavara Road (Wenlock Railway Node – Attavara KMC Hospital Jn.)
8	New Balmatta Road (Jyothi Circle – Avery Junction)
10	Don Bosco School Road (KMC Marcara – Avery Junction)
15a	Azizuddin Road (Lower Car Street – Bunder Police Station)
15b	Jumma Masjid Road (Lower Car Street – Bombay Lucky Junction)
19a	Arya Samaj Road (Arya Samaj KRR Rd Jn – Collector's Gate Circle)
19b	Balmatta Road (Jyothi Circle – Collector's Gate Circle)
20	Bengre Ferry Road (Port Rd Ansari Rd Jn – BMS Ferry Line)



The Figure 1-2 shows the roads considered for DPR 5 package.

G) EXISTING AND PROPOSED COMPONENTS IN THE PRESENT DPR

Rd. no.	Name of Rd.	Rd.		Length	Pavement	Median	SWD Details	Footpath	Street Light
		From	To	Mts	Type				
7a	**Milagres Cross Rd.**	KMC Central Library Jn.	Milagres Church Jn	183.00	Flexible	No	No	No	No
7c	**Nandigudda Rd.**	Attavar Rd.	Mglr. Railway Rd.	1021.00	Rigid	No	No	One side	One Side
8	**New Balmatta Rd.**	Jyoti circle	Ivory Junction	577.00	Flexible	No	One-side	One side	One Side
10	**Don Bosco hall cross Rd.**	KMC Mercara Trunk Rd.	Ivory Junction	375.00	Rigid	No	One-side	One side	No
15a	**Jumma Masjid Rd.**	Car Street	Bunder Police Station	595.00	Rigid	No	Two-side	Yes - Both Side	No
15b	**Port Rd.**	Bunder Rd.	Badriya School Jn.	330.00	Rigid	No	One-side	One side	No
19a	**Arya Samaj Rd.**	Balmatta Circle	Mangalore Hospital	717.00	Paver	No	Two-side	One side	One Side
19b	**Balmatta Road**	Jyoti circle	Arya Samaj Road Jn.	966.00	Rigid	Yes	Two-side	Two-side	Two-side
20	**Bendre Ferry Rd.**	Jumma Masjid	BMS Ferry Lane	1103.00	Flexible	No	One-side	No	No
	Total - V			**5867.00**					

Table 5 Existing Component of Smart Road Package – 05

Rd no	Name of Rd.	Rd.		Length	Pavement	Proposed Median	SWD	Footpath	Utility Conduits	Bus Shelter	Street Light	UGD
		From	To	Mts	Type							
7a	**Milagres Cross Rd.**	KMC Central Library Jn.	Milagres Church Jn	183.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Yes
7c	**Nandigudda Rd.**	Attavar Rd.	Mglr. Railway Rd.	1021.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
8	**New Balmatta Rd.**	Jyoti circle	Ivory Junction	577.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
10	**Don Bosco hall cross Rd.**	KMC Mercara Trunk Rd.	Ivory Junction	375.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
15a	**Jumma Masjid Rd.**	Car Street	Bunder Police Station	595.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
15b	**Port Rd.**	Bunder Rd.	Badria School Jn.	330.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
19a	**Arya Samaj Rd.**	Balmatta Circle	Mangalore Hospital	717.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
19b	**Balmatta Road**	Jyoti circle	Arya Samaj Road Jn.	966.00	Rigid	Median	No	Both Side	Both Side	Yes	Yes	Existing UGD
20	**Bendre Ferry Rd.**	Jumma Masjid	BMS Ferry Lane	1103.00	Rigid	No	Both Side	Both Side	Both Side	No	Yes	Existing UGD
	Total			**5867.00**								

Table 6 Proposed Components Smart Road Package -05

H) COST (WITH COMPONENT WISE PIE CHART),

Summary of the works broadly summarized below:

Table 7 Summary of Cost – Smart Road Package – 05

Sr. No.	Description	Cost In INR
1	Road and Other Works	37,34,90,066
2	Street Lighting	64,63,562
3	Landscape Work	22,38,546
	Construction Cost Sub Total	**38,21,92,174**
	GST @ 12% -Civil Construction Cost (Refer 1.0 Abstract)	4,40,83,122
	Provision for Third Party Damages and Maintenance at 1 st Year(DLP-	28,83,930
	GST @12% on DLP Cost Items (Refer 5.1 Abstract)	2,65,467
	Maintenance Cost of 2nd,3rd and 4th Year	1,21,84,243
	GST @12% on Maintenance Cost	11,81,659
	Escalation and Tender Premium @10%	382,19,217
	Add 3% Contingency	114,65,765
	Miscellaneous and Rounding off	24,423
	Grand Total	**49,25,00,000**

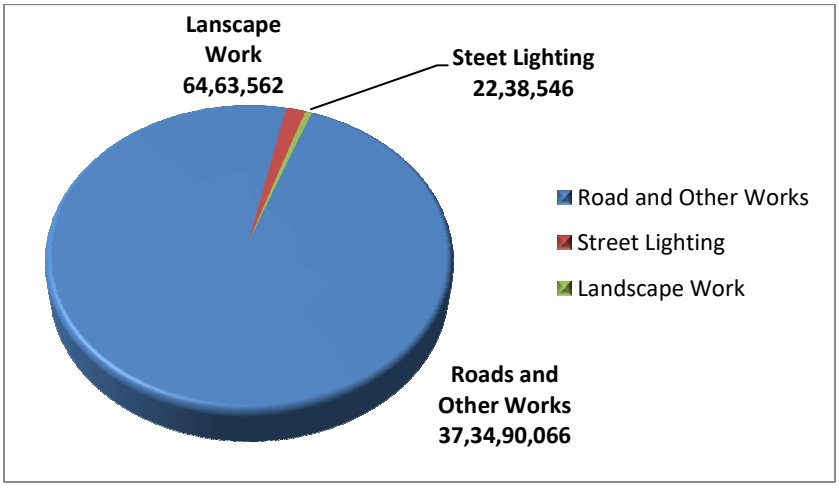


Figure 3 Pie Chart Showing Major Components

I) PROJECT FUNDING

A matrix of the details in the DPR shall be shown as mentioned below for existing situation and proposed components in the executive summary:

Sr. No.	Name of the Project	Value of the Project (in INR Cr)	DPR COST (in INR Cr)
1	Improvements to Nehru Maidan Road from Clock Tower to AB Shetty Circle	7.560	7.560
2	Smart Road Package 2	12.500	13.76
3	Smart Road Package 3	42.060	47.40
4	Smart Road Package 4	48.000	48.00
5	Smart Road Package 5	49.000	49.25
6	Smart Road Package 6	48.000	
7	Smart Road Package 7	40.520	

Table 8 Smart Road Packages – Cost as per SCP and DPR

Chapter 1 PROJECT BACKGROUND

1.1. Mangaluru Smart City Proposal

Karnataka Urban Infrastructure Development & Finance Corporation Limited (KUIDFC) is the State Level Nodal Agency (SLNA) for the Smart Cities Mission in Karnataka. ***Mangaluru was a proud Participant in second round of this Challenge and now aspires to translate the vision i.e. the broad*** components ***across both 'area-based' and 'pan-city' heads identified in the Smart City Proposal (SCP) into Reality.***

The implementation of the Mission at the City level will be done by a Special Purpose Vehicle (SPV) i.e. Mangaluru Smart City Limited (MSCL) constituting of board of directors from State Government as well as Mangaluru Municipal Corporation and nominees from the Government of India

M/s Wadia Techno-Engineering Services Limited (Lead Member) in consortium with M/s Louis Berger Consulting Private Limited & Centre for Development of Advanced Computing has been appointed as the Project Management Consultant (PMC) for Implementation of the Smart City Mission Projects in Mangaluru City.

The expected time of completion of the assignment is 60 months.

1.1.1. *The Objective*

The objective of the assignment is to provide direct assistance to Mangaluru Smart City Limited of the Mangaluru City to realize the vision of the city, contemplated in the SCP, by designing developing, managing and implementing the Smart City Projects of Smart City Mission Guidelines on the following two outputs:

- Output1: Area Based Development (ABD)
- Output2: Pan-city Initiative

1.2. Approach towards implementation of Smart Components

1.2.1. *Need for Intervention*

The existing road infrastructure and transport facilities in Mangalore are proving to be inadequate to meet the requirements of the city. 63% of the roads have speeds below 30 kmph as noted during the Comprehensive Traffic and Transportation Study of Mangalore. The delay is both due to traffic signals and interference of traffic movements, such as turning vehicles, parking and un-parking vehicles, pedestrians etc. Due to substantial increase in the number of city buses in operation in addition to mixed flow of heavy traffic, the city is facing many traffic problems.

Further, with the increase in the commercial activity in some of the important areas like Hampankatta, Bejai, etc., there is an increased demand for better pedestrian facilities. The increase in vehicular traffic has given rise to widening the carriageway width to accommodate the vehicles resulting in reduction in the size of the foot paths. This in turn has given room for pedestrians to spill over to the carriageway, thereby affecting the flow of vehicles. Considering the present scenario the main arterial roads and junctions require up gradation to improve the traffic and transport facilities for the citizens. There is hence a need to transform the existing roads with above concerns into smart roads as depicted in diagram below

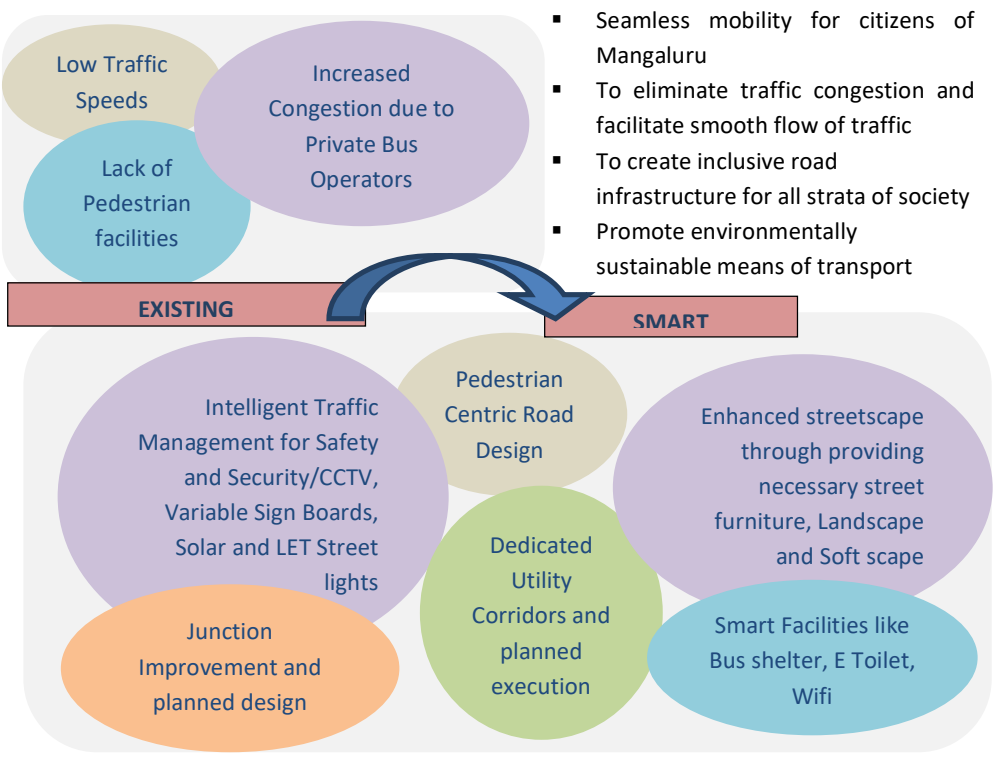


Figure 4 Vision methodology for Smart Roads in the city

1.2.1. Proposed Interventions

The proposed intervention aims to achieve the following:

- Seamless mobility for citizens of Mangaluru
- To eliminate traffic congestion and facilitate smooth flow of traffic
- To create inclusive road infrastructure for all strata of society
- Promote environmentally sustainable means of transport

Smart Roads include Four Broad Objectives, namely:

1) **EFFICIENT AND SAFE STREETS**: This involves road re-channelization whereby the effective width of the carriageway is reduced in order to achieve systemic improvements. Roads with clearly demarcated spaces for vehicles, pedestrians, cyclists and dedicated on-street parking to minimize conflicts between vehicular and pedestrian traffic.
2) **RESILIENT STREETS**: Streets with defined utility corridor including undergrounding overhead utilities where upgraded utilities can withstand severe natural and man-made disasters. Streets that provide infrastructure allowing safe walking experience in night through pedestrian lighting and clean public space through dustbins at regular intervals.
3) **INCLUSIVE STREETS**: Universal accessible design that allow safe walking experience with shaded walkways to all citizens and specific facilities for elderly and people with special needs.
4) **STREETS AS PUBLIC SPACES**: Streets that provide spaces outside our homes for social, cultural or intellectual interactions, to walk or to just breathe fresh air.

Figure 5 Proposed interventions for the Selected Roads to be developed as smart roads

The Smart Road proposal would consist of the following specific interventions:

Details of proposed smart elements along the Road are covered in subsequent sections.

1.2.2. Expected Benefits

The proposed up gradation of roads to Smart Roads would provide the following benefits to Mangaluru city:

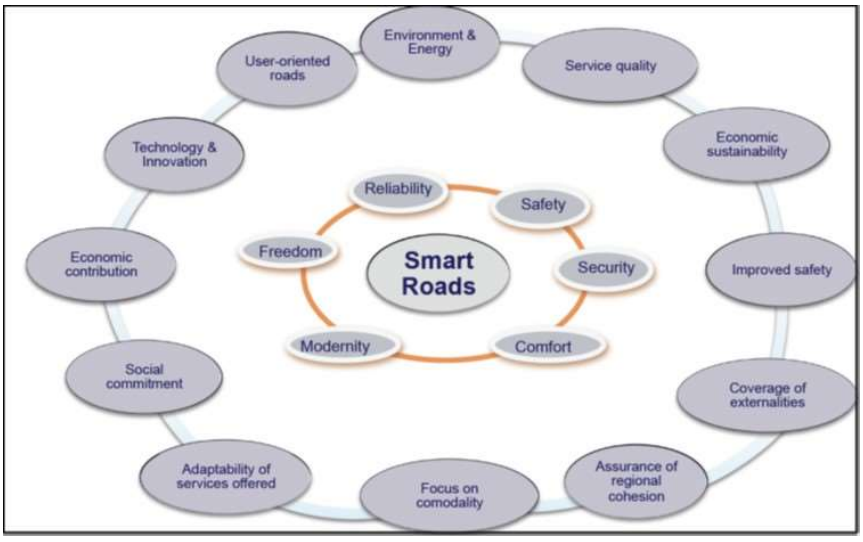


Figure 6 Benefits of developing Smart roads

1.2.3. Assumptions/Prerequisites

The assumptions for implementation of the Smart road are:

- There is no land acquisition involved and the selected road stretches are free of unauthorized encroachments
- The information about location of underground utilities and their alignment is available with the local authority
- Mangaluru City Corporation will facilitate the development of this project through facilitation of various statutory approvals and consultation with stakeholders
- 30% of median lighting poles to be replaced by new lighting poles.

1.2.4. Stakeholders/ Organizations involved

- Citizens
- Mangaluru Smart City Limited (MSCL)
- Mangaluru City Corporation (MCC)
- Mangaluru Smart City PMC
- Karnataka Public Works Department – Mangalore Division
- Traffic Police / RTO
- Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC)
- Mangalore Electricity Supply Company Limited (MESCOM)
- Karnataka State Road Transport Corporation (KSRTC)
- Private Bus Operators Association
- City Level Advisory Forum (CLAF)

1.2.5. Target Beneficiaries

The proposed up gradation of roads to Smart Roads would benefit the following:

- **Citizens**: The citizens would get better transport facilities for their mobility needs. The road improvement project would reduce traffic congestion; thereby result in travel time savings for the citizens. Smart roads also offer multiple mobility options such as walking, cycling, and public transport or through private vehicles. The upgraded roads would be

inclusive to all citizens, i.e. would have facilities that would make them accessible to elderly or physically challenged persons.

- **Local Authority/ MCC**: The municipal corporation would get upgraded roads with more traffic handling capacity, smooth traffic flow and lesser congestion. Roads upgraded with state-of-the-art technology would result in fuel savings and lesser maintenance costs. Smart Roads would also help the local government in energy saving through energy efficient LED street lighting.
- **Local Economy**: The improved mobility and reduced travel times would result in improving the productivity of the citizens and thus benefit the local business and the city's economy.

1.2.6. Objective of the Report

The purpose of the Detailed Project Report is to provide details of various considerations and the elements proposed for the DPR-5 Smart Road. It aims to give a basic design idea to all the stakeholders before proceeding for final design and estimates.

1.2.7. Structure of the Report

This report is organized as follows:

- **EXECUTIVE SUMMARY**
- **Chapter 1 – Introduction**
- **Chapter 2 – Project Background**
- **Chapter 3 – Proposed Design**
- **Chapter 4 – Timeline for Execution**
- **Chapter 5 – Monitoring and Evaluation**
- **Chapter 6 – Cost Estimates**
- **Chapter 7 – Drawings**
- **Annexures**

1.3. Area Description

The details in Nutshell for the ABD area planning as well as few important components are graphically shown below:

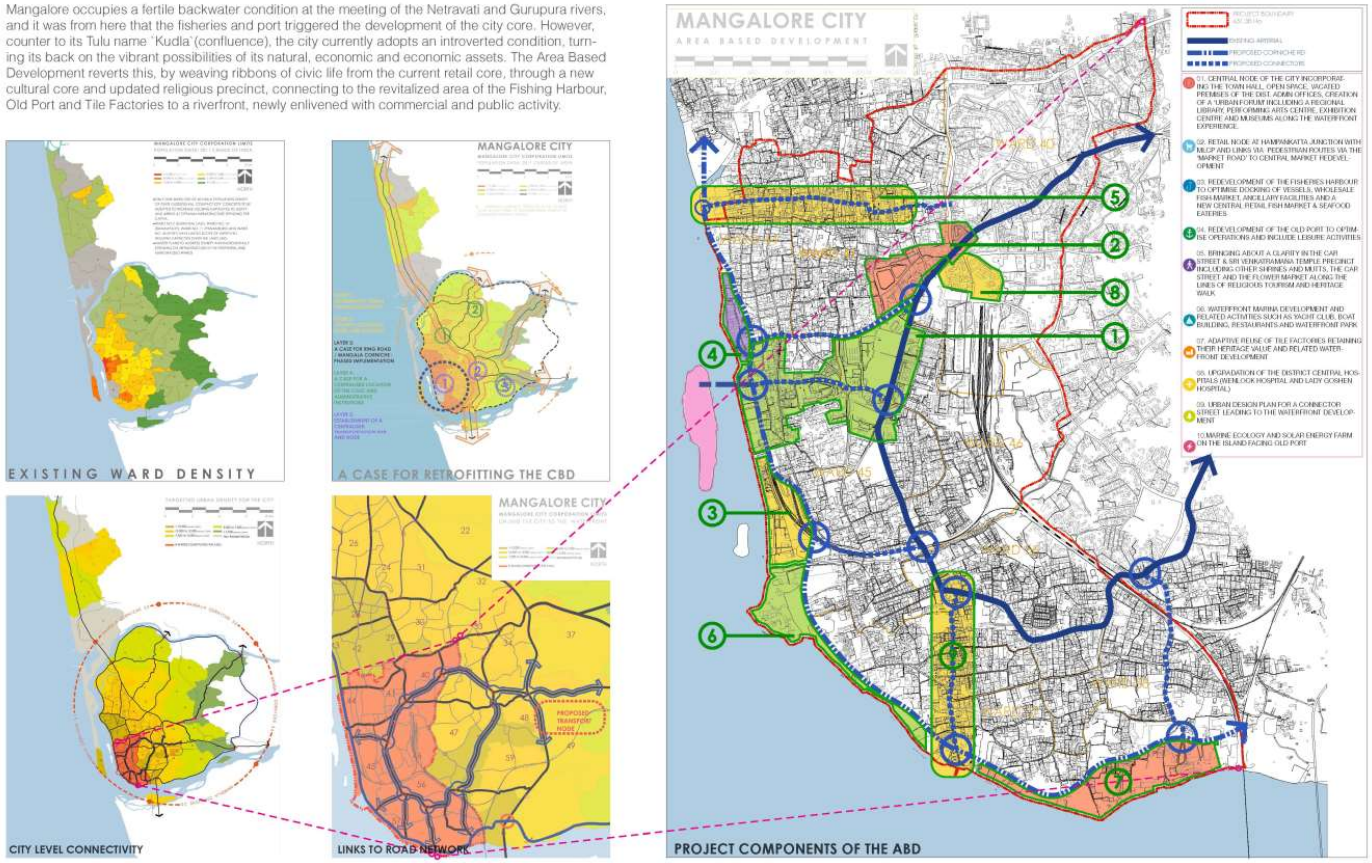


Figure 7 MANGALURU ABD AREA SHOWING IDENTIFIED PROJECT AS PER SMART CITY PROPOSAL

Phasing of Road Packages:

The Entire Road Packages considered are based on the ABD area development to improve the mobility. The Packages initiated with the central part and heart of the city called Maidan road, hence the first package included the Maidan road- starting from Clock Tower to AB Shetty Circle. Package – 02 included the roads surround to the Maidan road as the Maidan is point of attraction and inviting lots of social and cultural activities. However considering one of the important project of Redevelopment of Central market, the Bibi Alabi road and few other roads around Central Market were planned for later packages as the construction of Central Market can affect the roads. The Package -03, 04 and all other projects are conceived in the same fashion, connecting these roads.

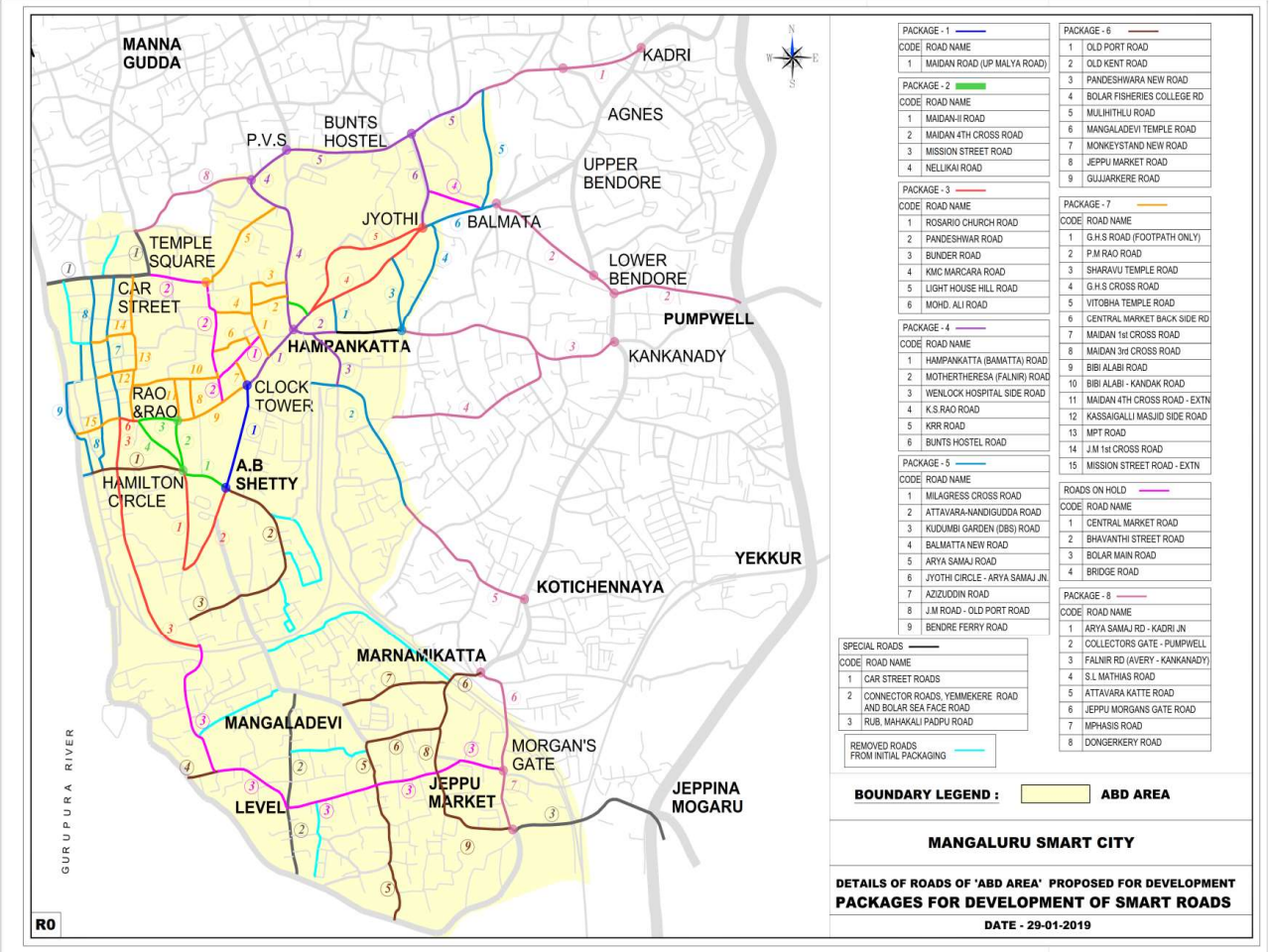


Figure 8 Smart Road Packaging

1.4. Comprehensive plan

Mangalore occupies a fertile backwater condition at the meeting of the Netravati and Gurupura rivers, and it was from here that the fisheries and port triggered the development of the city core. However, counter to its Tulu name 'Kudla' (confluence), the city currently adopts as introverted condition, turning its back on the vibrant possibilities of its natural economic and economic assets. The Area Based Development reverts this, by weaving ribbons of civic life from the current retail core, through a new cultural core and updated religious precinct, connecting to the revitalized area of the Fishing Harbour, Old Port and Tile Factories to a riverfront, newly enlivened with commercial and public activity. The major aim is to connect the Water Front with the city

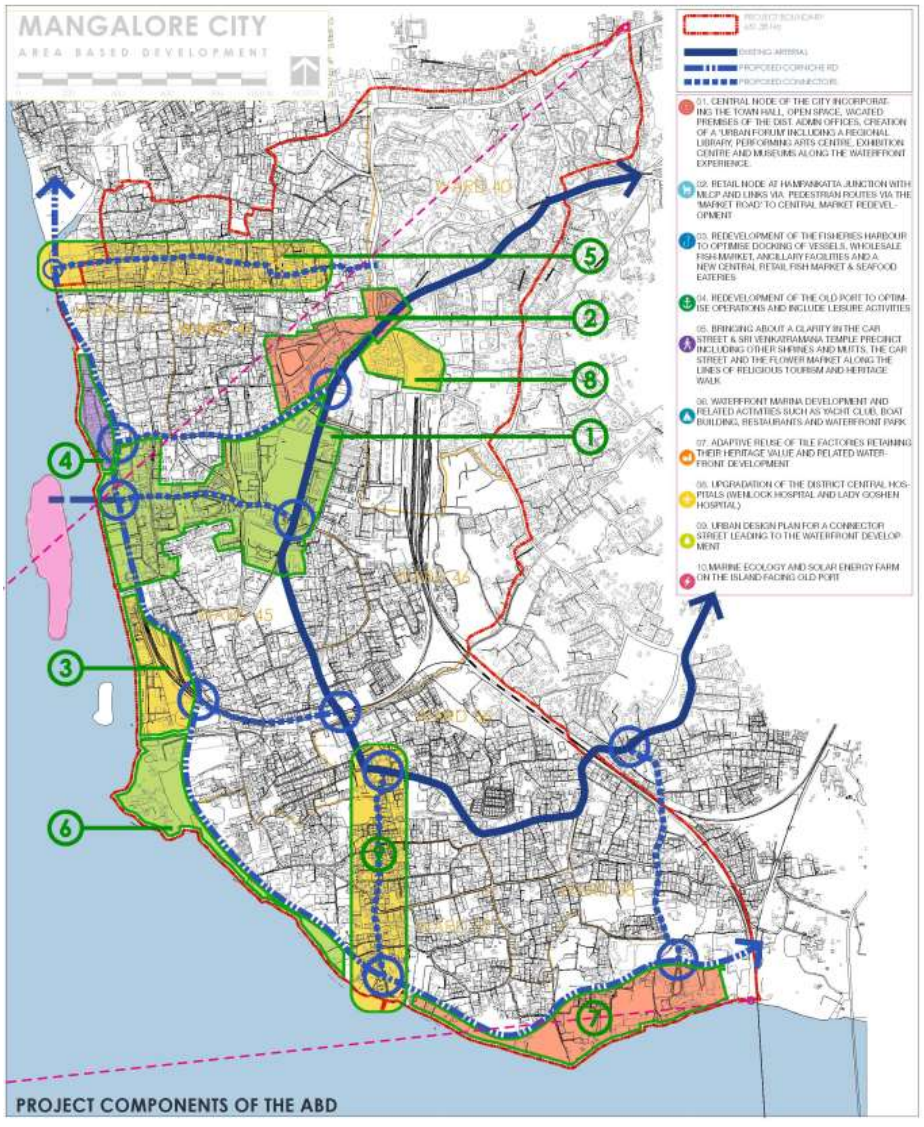


Figure 9 Major Project Components of ABD Area under Smart City

Chapter 2 FIELD INVESTIGATIONS & ANALYSIS

2.1 Site Reconnaissance and Situation Analysis

Detailed Site Reconnaissance was carried out along the selected roads to assess the existing situation in terms of pavement condition, traffic situation/movements, existing facilities/structures, smart elements that can be proposed along DPR-5 Smart Road. Section below describes brief of existing condition of DPR-5 Smart Road

2.1.1 Arya Samaj Road

It stretches from KRR Road-Arya Samaj Rd Jn to Balmatta Rd.

Road Details:

- Total length of road = 595 m
- Min. width = 6.495m
- Max. Width = 15.735 m
- Slope: 0.25%
- Type of Carriageway: Rigid at junction and later paver blocks. Road condition is good.
- Lane configuration: 2 Lane carriageway two way. No Median.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drains is existing on one side of the road.
- Waterline is present on one side of the carriage way.

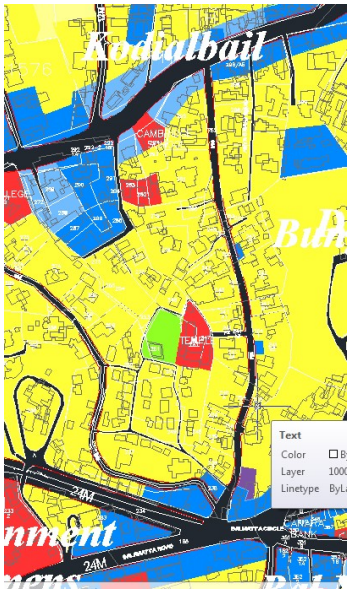


Figure 10 Master Plan Details – Aruya Samaj Road

Figure 11 Existing Situation – Arya Samaj Road

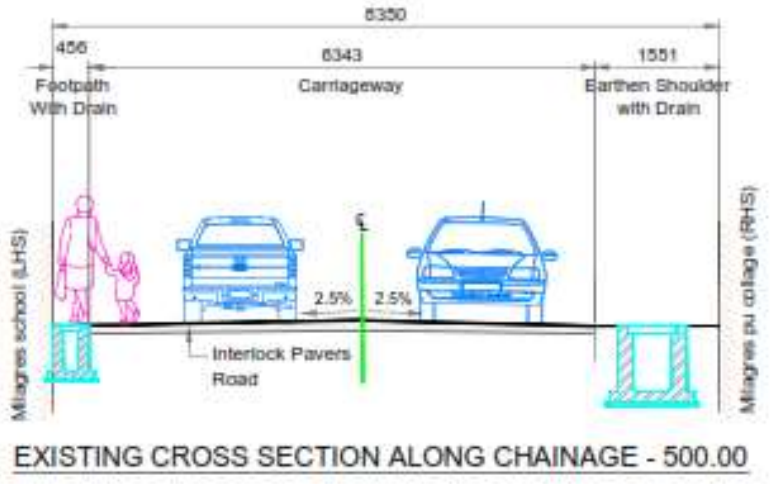


Figure 12 Existing Cross Section Arya Samaj Road

OBSERVATIONS:

- On the northern and southern sides of the road, Commercial land use is observed while to the Eastern and Western sides of the road, residential landuse is observed.
- No on-street parking is observed on the street as there is no ample space on the road.

The proposed ROW as per MUDA master plan is 9 m.

2.1.2 Balmatta Road

It stretches from Jyoti circle to Arya Samaj Road jn.

Road Details:

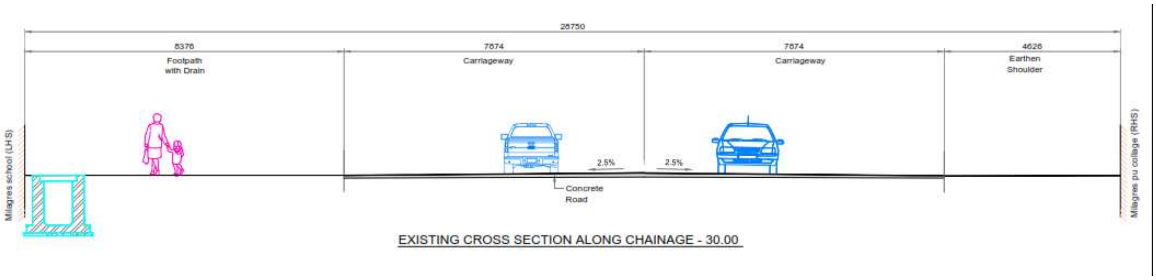
- Total length of road = 330 m
- Min. width = 23.402 m
- Max. Width = 28.750 m
- Slope: 0.25%
- Type of Carriageway: mostly Rigid road but at junction paver blocks. Road condition is good.
- Lane configuration: 4 Lane carriageway two way. Median present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drains are existing on both sides of road.
- Waterline is present on one side of the carriage way.

Figure 13 Master Plan – MUDA Details – Balmatta Road

Figure 14 Existing Situation – Balmatta Road



Existing Cross Sections – Balmatta Road

OBSERVATIONS:

- Surrounding the road, mostly commercial and institutional landuse is prevalent.
- Near junctions and footpaths, paver blocks are laid.
- On-street parking is observed on the street.

The proposed ROW as per MUDA master plan is 24 m.

2.1.3 Milagres Cross Road

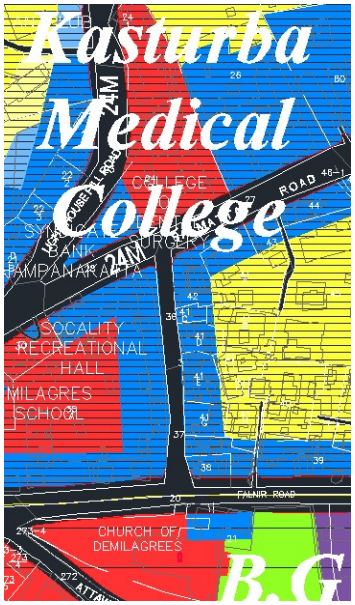
It stretches from KMC Central Library Jn to Mother Theresa Church jn.

Road Details:

- Total length of road = 183 m
- Min. width = 8.083 m
- Max. Width = 10.556 m
- Slope: 0.25%
- Type of Carriageway: Flexible road. Road condition is poor.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is not present.
- Waterline is present on one side of the carriage way.



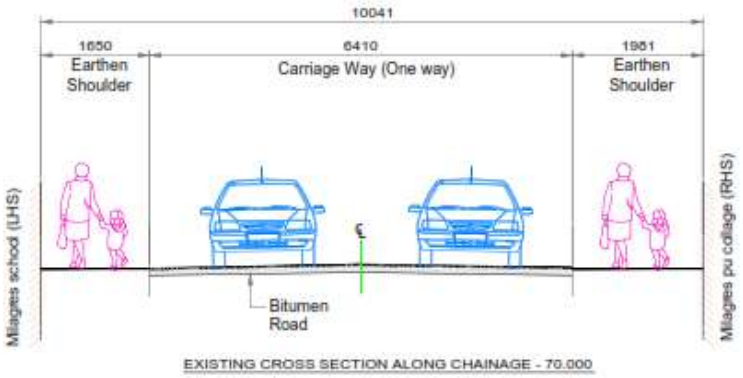


Figure 15 Existing Cross Section, Site Photographs and MUDA Master Plan layout of Milagres Cross Road

OBSERVATIONS:

- Surrounding the road, mostly commercial landuse is prevalent.
- Near junctions, rigid pavement is present.
- On-street parking is observed on the street despite narrow road.
- Road condition is poor

2.1.4 Attavar Nandigudda Road

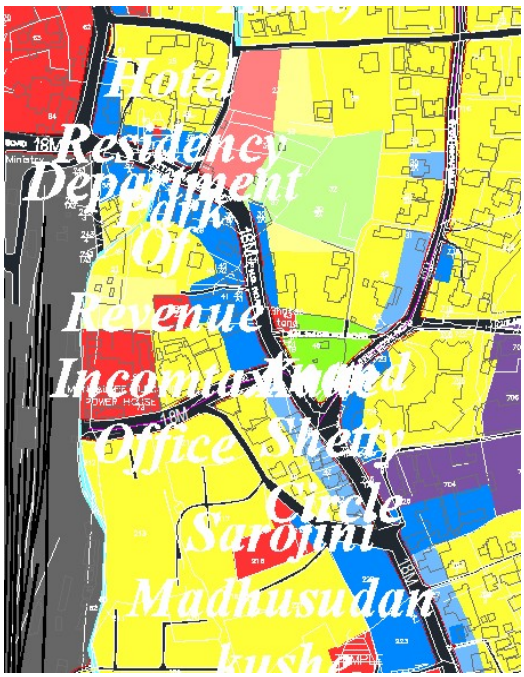
It stretches from Wenlock Junction to KmC hospital.

Road Details:

- Total length of road = 1021 m
- Min. width = 8.78 m
- Max. Width = 23.80 m
- Slope: 0.25%
- Type of Carriageway: Rigid road. Road condition is Good.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is not present.
- Waterline is present on both sides for a portion of the road. Later only on one side of the carriage way.



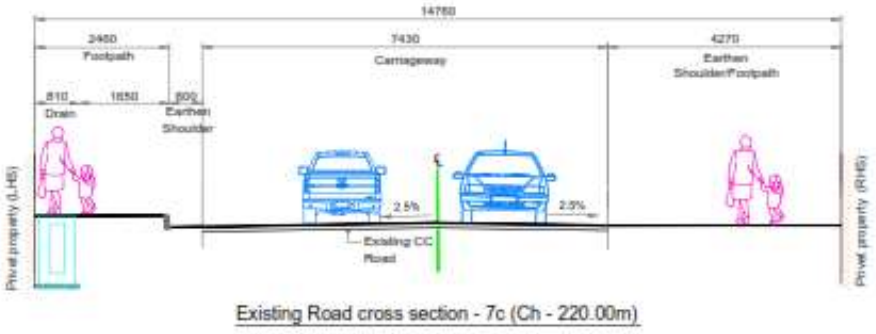


Figure 16Existing Cross Section, Site Photographs and MUDA Master Plan layout of Attavar Nandigudda Road

OBSERVATIONS:

- Surrounding the road, mostly commercial landuse is prevalent.
- On-street parking is observed and for most part, paver are provided for authorised parking.

The proposed ROW as per MUDA master plan is 18 m.

2.1.5 New Balmatta Road

It stretches from Avery Junction to near Jyoti Circle.

Road Details:

- Total length of road = 577 m
- Min. width = 6.19 m
- Max. Width = 17.86 m
- Slope: 0.25%
- Type of Carriageway: Flexible road. Road condition is poor at few places but rest is Good.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is present on one side.
- Waterline is present on one side of carriageway

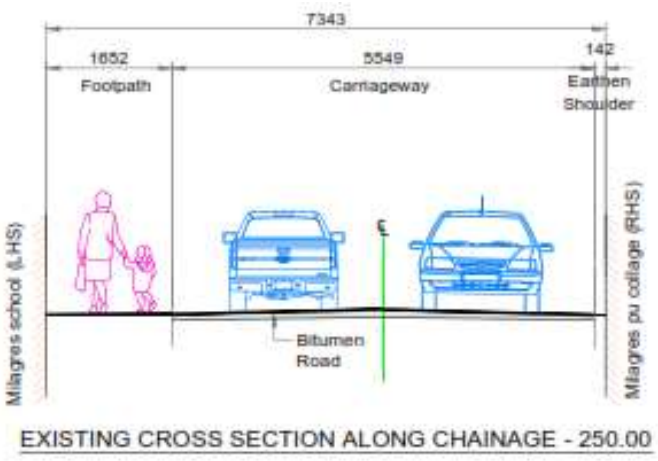


Figure 17 Existing Cross Sections, Site Photographs and MUDA Master Plan layout of New Balmatta Road

OBSERVATIONS:

- Surrounding the road, mostly residential landuse is prevalent.
- No On-street parking is observed.

The proposed ROW as per MUDA master plan is 9 m.

2.1.6 Kudumbi Garden (DBS) Road

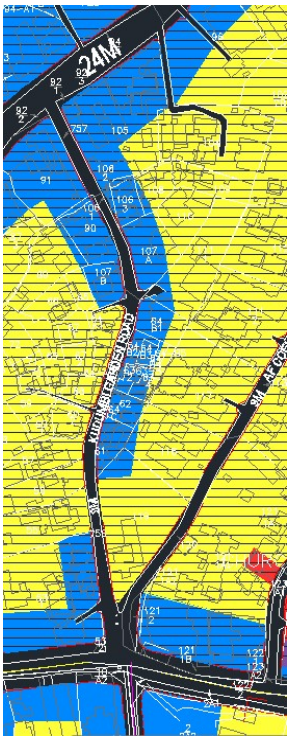
It stretches from Avery Junction to near KmC Marcera Road.

Road Details:

- Total length of road = 375 m
- Min. width = 8.54 m
- Max. Width = 12.19 m
- Slope: 0.25%
- Type of Carriageway: Rigid road. Road condition is Good.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is present on one side.
- Waterline is present on one side of carriageway.



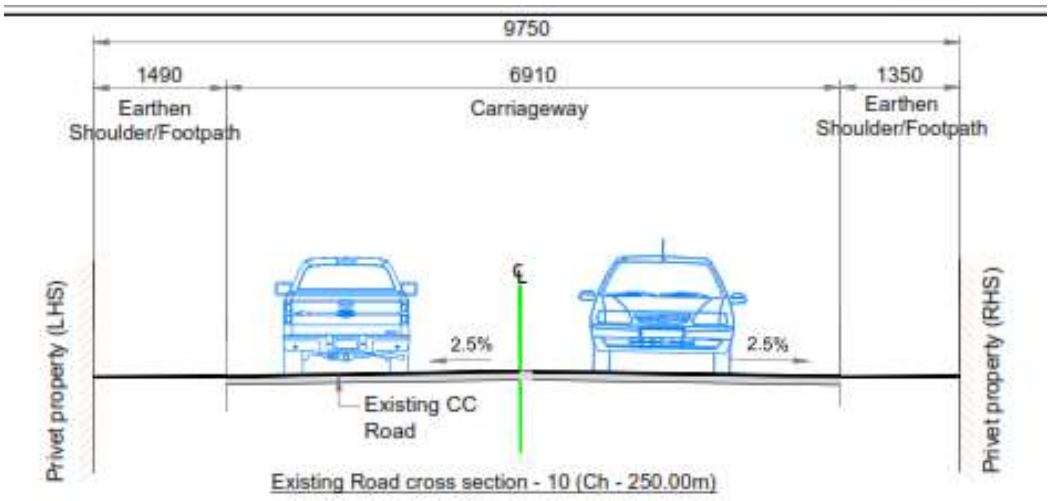


Figure 18 Existing Cross Sections, Site Photographs and MUDA Master Plan layout of Kudumbi Garden (DBS) Road

OBSERVATIONS:

- Surrounding the road, mostly commercial and residential landuse is prevalent.
- No much On-street parking observed.
- Most space beside C/w is earthern.

The proposed ROW as per MUDA master plan is 9 m.

2.1.7 Azizuddin Road

It stretches from Lower Carstreet Road to Bunder Police Station Jn.

Road Details:

- Total length of road = 717 m
- Min. width = 8.67 m
- Max. Width = 11.10 m
- Slope: 0.25%
- Type of Carriageway: Rigid road. Condition is poor at few places but mostly is Good.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is present on both sides.
- Waterline is present on one side of carriageway.

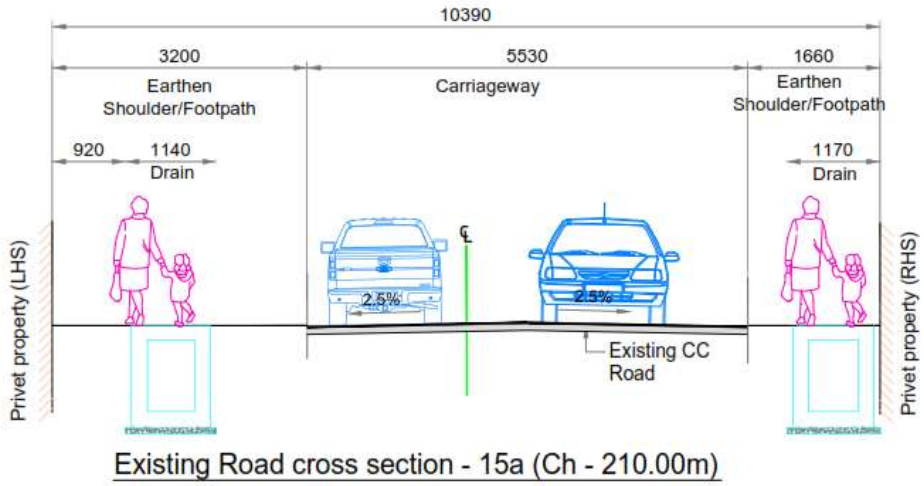


Figure 19 Existing Cross Sections, Site Photographs and MUDA Master Plan layout of Azizuddin Road

OBSERVATIONS:

- Surrounding the road, mostly commercial and residential landuse is prevalent.
- On-street parking is observed as te road houses lots of automobile repair shops.

The proposed ROW as per MUDA master plan is 24 m.

2.1.8 Jumma Masjid Road

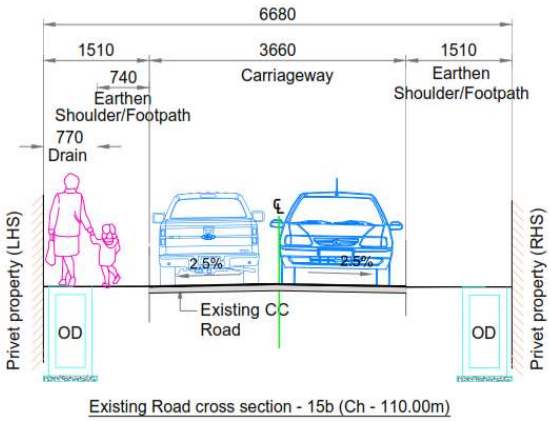
It stretches from Lower Carstreet Road to Bombay Lucky Jn.

Road Details:

- Total length of road = 966 m
- Min. width = 5.49 m
- Max. Width = 9.29 m
- Slope: 0.25%
- Type of Carriageway: Rigid and flexible road. Condition is poor at most places.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is present on both sides.
- Waterline is present on one side of carriageway.



Existing Road cross section - 15b (Ch - 110.00m)

Figure 20 Existing Cross Sections, Site Photographs and MUDA Master Plan layout of Jumma Masjid Road

OBSERVATIONS:

- Surrounding the road, mostly commercial landuse is prevalent.
- On-street parking is observed as the road houses lots of automobile repair shops.
- Very congested road, due to movement of trucks and HOVs
- Mix of Rigid and flexible roads creating potholes at junctions.

The proposed ROW as per MUDA master plan is 18 m.

2.1.9 Bengre Ferry Road

It stretches from Jumma Masjid to BMS Ferry Lane.

Road Details:

- Total length of road = 1103 m
- Min. width = 5.01 m
- Max. Width = 33.73 m
- Slope: 0.25%
- Type of Carriageway: Flexible road. Road Condition is Good.
- Lane configuration: 2 Lane carriageway two way. Median not present.

Existing Utilities:

- The electrical lines are present above ground
- Storm water drain line is present on one side of the road.
- Waterline is present on both sides of carriageway.

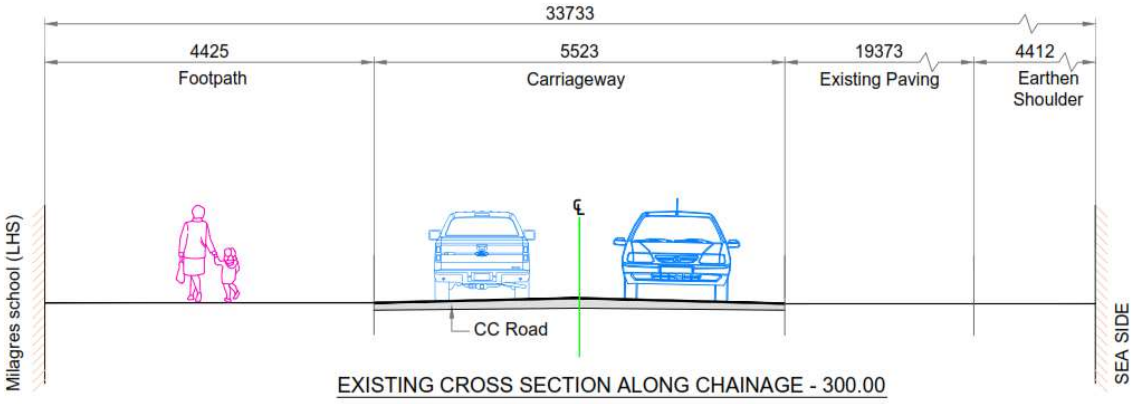


Figure 21 Existing Cross Sections, Site Photographs and MUDA Master Plan layout of Bengre Ferry Road

OBSERVATIONS:

- Surrounding the road, mostly commercial and institutional landuse is prevalent.
- On-street parking is observed i.e. mostly trucks and HOVs.
- Very congested road, due to movement of trucks and HOVs
- Mix of Rigid and flexible roads creating potholes at junctions creating traffic blocks.

2.2 Road Inventory Survey

A detailed road inventory was done along the selected roads. At onset, the Ground Control Points (GCPs) were established using precision DGPS at appropriate intervals which shall be captured during DTM (Digital Terrain Model) for further geo referencing and Traversing using Total Station.

All the existing and proposed features, such as land-use, limits of right-of-way, embankment, structures, intersecting roads, existing utilities, electric and telephone installations (both O/H as well as underground), access roads, connectors, wayside amenities, safety structures, buildings, fencing and trees, street lights along the median/road side, oil and gas lines etc. falling within the extent of survey complete and levels were picked up (using Auto Level) at an interval of 10m X 10m grid.

2.3 Trial pits

The Cement Concrete roads are proposed to be retained as they are constructed recently about 3-5 years back. The bituminous roads are proposed to be replaced with Cement Concrete roads. For this purpose samples are taken for investigations and are being analysed. The photographs are provided below:

Figure 22 Trial Pits Survey Site Photographs Traffic Surveys and Analysis

2.4 Survey Introduction

2.4.1 Project Background

This chapter presents the traffic surveys, analysis and future strategy for Smart Roads under Package 5, referred to as DPR-5.

Mangalore Smart City Limited (MSCL) is implementing the Smart City Proposals with the help of the Project Management Consultant. Development of Smart Roads is one of important projects in the Smart City Proposal. Safe pedestrian movement along with smart features is key in the development of the Smart Roads.

Based on the roads and junction identified under DPR-5, detailed primary surveys and investigation were carried out. Table 3-1 below defines various Traffic surveys and investigations carried out along the identified Road

The overall objective was to capture traffic flow characteristics, travel pattern; speed characteristics, on traffic passing through the project road and other characteristics related to miscellaneous requirements on the project road.

2.4.2 Scope of Work

The scope of the work comprises of development of the following roads:

1. Milagres Cross Road (KMC Marcara Road – Mother Theresa Road Junction)
2. Nandigudda Attavara Road (Wenlock Railway Node – Attavara KMC Hospital Jn.)
3. New Balmatta Road (Jyothi Circle – Avery Junction)
4. Don Bosco School Road (KMC Marcara – Avery Junction)
5. Azizuddin Road (Lower Car Street – Bunder Police Station)
6. Jumma Masjid Road (Lower Car Street – Bombay Lucky Junction)
7. Arya Samaj Road (Arya Samaj KRR Rd Jn – Collector's Gate Circle)
8. Balmatta Road (Jyothi Circle – Collector's Gate Circle)
9. Bengre Ferry Road (Port Rd Ansari Rd Jn – BMS Ferry Line)

The Traffic Volume Counts were conducted as per guidelines illustrated in IRC: SP: 19 – 2001, 'Manual for Survey, Investigation and Preparation of Road Projects'.

The Figure attached here shows the traffic survey in progress at the Project site. For carrying out the counts, the vehicles were grouped under the categories given in Table below in Table 10.

Figure 23 Survey work in progress

2.4.3 Survey Types and Locations

Surveys were conducted at 8 different locations on these roads and the schedule of these traffic surveys is given in table below:

Table 9 Traffic Surveys and Investigations conducted along the DPR-5 Roads

S.No.	Location	Survey	Schedule
1	Milagres Cross Road	TMC	04-Dec-18
2	Nandigudda Road	TMC	04-Dec-18
3	New Balmatta Road	TMC	30-Nov-18
4	Don Bosco Hall Cross Road	TMC	30-Nov-18
7	Arya Samaj Road	TMC	28-Nov-18
5	Jama Masjid Road	TVC	19-22 Mar 18
6	Port Road	TMC	01-Dec-18
8	Bengre Ferry Road	TVC	19-21 Mar 18
*(*TMC – Turning Movement Count, TVC – Traffic Volume Count)*			

Table 10 Traffic Surveys - Vehicle Classification system

Category	Examples of Vehicle Types
Two Wheelers	Scooters, Bikes, Motor cycles and Mopeds
Three Wheelers	Auto Rickshaw
Car	Car, Jeep, Taxi, and Vans
Bus	Mini Bus, Government Bus, Private Bus
Trucks	Light Commercial Vehicle (LCV), 2, 3, 4, 5, 6 and >6 Axle Trucks
Other	Tractor, Tractor & Trailer
Non-Motorized	Bicycle, Cycle Rickshaw, Animal drawn vehicles, Hand Cart

Intersection turning movement surveys have been carried out at all the major intersection locations. Classified traffic volume counts of all types of vehicles have been made separately for each direction including left and right turning traffic. The surveys have been conducted for successive 15 minutes interval for a period 24 hours.

The complete details of above mentioned primary Traffic Survey and Investigations have been enclosed as Annexure-I to the Report

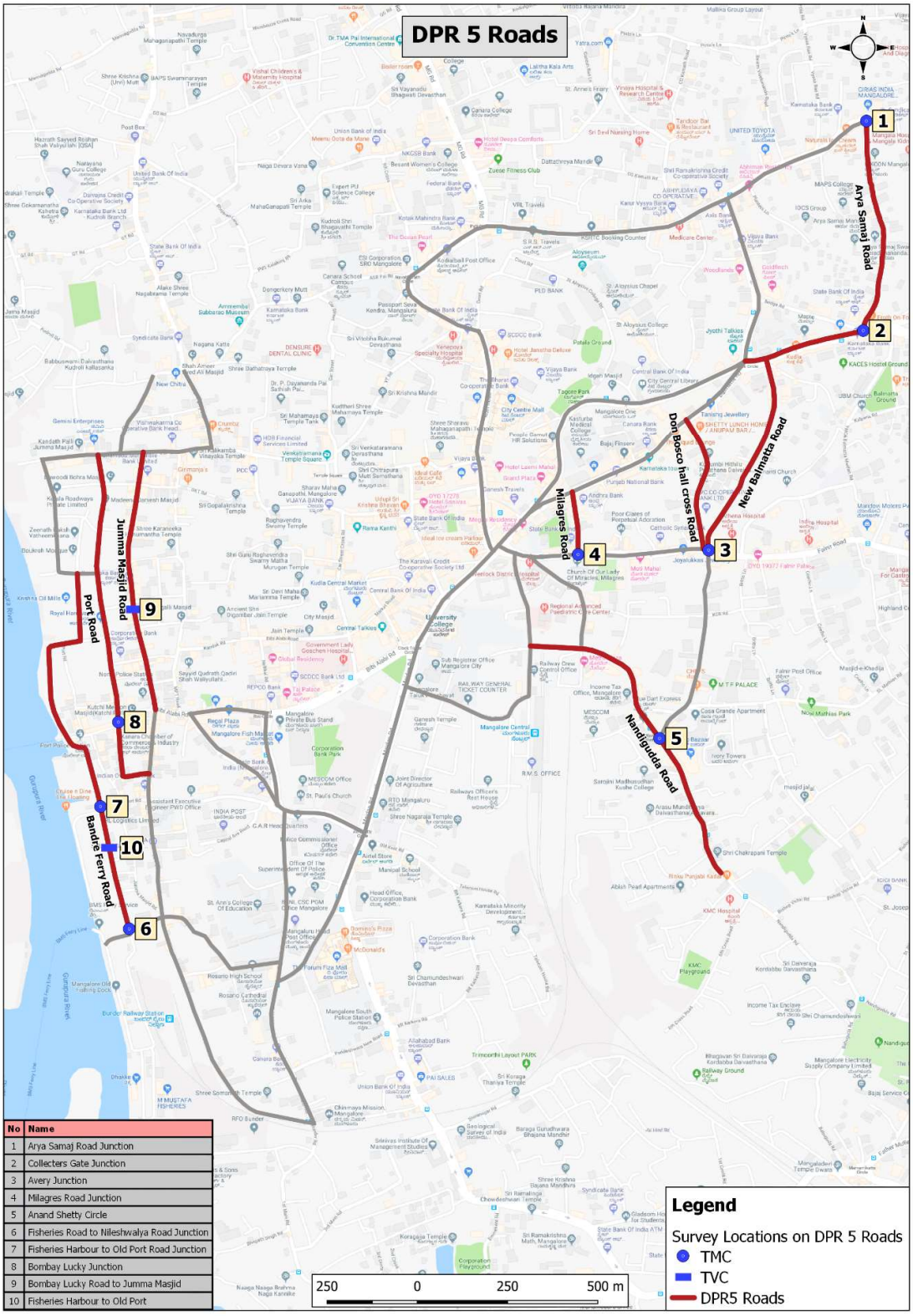


Figure 24 Traffic Survey Location

2.4.4 TRAFFIC ANALYSIS

2.4.4.1 Methodology

The methodology adopted for the study is implemented through the following steps:

1. Establish the base line traffic on the corridor based on the traffic surveys and analysis.
2. Estimate the future traffic levels with appropriate growth rate.
3. Assess the capacity of the road and suggest measures.

2.4.4.2 Classified Traffic Volume Counts

Traffic studies are required to assess the intensity of traffic vis-à-vis the capacity (service volume) of the road for the present, as well as, future.

Classified traffic volume counts on project roads and at important junctions were conducted and analyzed for following traffic characteristics of the surveyed roads:

- Average Daily Traffic (ADT)
- Hourly Variation
- Composition of ADT
- Annual Average Daily Traffic (AADT)

The various vehicle types having different sizes and characteristics were converted into equivalent Passenger Car Units. The Passenger Car Unit (PCU) factors recommended by Indian Road Congress in "*Guidelines for Capacity of Urban Roads in Plain Areas"* (IRC-106-1990) have been used for conversion, and are presented in table below:.

Vehicle Type	Equivalent PCU Factors	
	Percentage Vehicle Type in Traffic Stream	
	5%	10% and above
1. Two Wheelers/Motor Cycle or Scooter	0.5	0.75
2. Passenger Car, Pick-up van	1.0	1.0
3. Auto-rickshaw	1.2	2.0
4. Light Commercial Vehicle	1.4	2.0
5. Truck or Bus	2.2	3.7
6. Agricultural Tractor Trailer	4.0	5.0
7. Cycle	0.4	0.5
8. Cycle Rickshaw	1.5	2.0
9. Tonga (Horse drawn vehicle)	1.5	2.0
10. Hand Cart	2.0	3.0

Table 11 PCU Factors Adopted for Study

2.4.4.3 Annual Average Daily Traffic (AADT)

The traffic survey data is analyzed and the Average Daily Traffic (ADT) is presented below

Table 12 Average Daily Traffic

Mode	Milagres Cross Road	Attavara-Nandigudda rd 1	Attavara Nandigudda rd 2	Don Bosco Hall Cross Road	New Balmatta Road
2w	2,991	13,481	10,720	4,935	4,913
3w	3,083	6,884	4,611	2,262	4,321
Car/Van	1,598	4,486	4,667	2,666	3,257
Mini Bus	24	69	93	19	40
Bus	50	273	51	12	-
MLCV	72	329	258	120	136
LCV	4	49	32	16	3
2 Axle Truck	11	43	26	7	1
3 Axle Truck	-	-	-	-	-
MAV	-	-	-	-	-
Tractor	-	-	1	-	-
Tractor+Trailer	-	-	-	-	-
Cycle	4	57	50	10	16
Cycle rickshaw	-	-	-	-	-
Animal Drawn	-	-	-	-	-
Hand Cart	-	-	-	-	-
Total Veh	**7,837**	**25,671**	**20,509**	**10,047**	**12,687**
Total PCU	**10,254**	**29,577**	**22,555**	**11,106**	**15,789**

Mode	Milagres Cross Road	Attavara-Nandigudda rd 1	Attavara Nandigudda rd 2	Don Bosco Hall Cross Road	New Balmatta Road
2w	2,991	13,481	10,720	4,935	4,913
3w	3,083	6,884	4,611	2,262	4,321
Car/Van	1,598	4,486	4,667	2,666	3,257
Mini Bus	24	69	93	19	40
Bus	50	273	51	12	-
MLCV	72	329	258	120	136
LCV	4	49	32	16	3
2 Axle Truck	11	43	26	7	1
3 Axle Truck	-	-	-	-	-
MAV	-	-	-	-	-
Tractor	-	-	1	-	-
Tractor+Trailer	-	-	-	-	-
Cycle	4	57	50	10	16

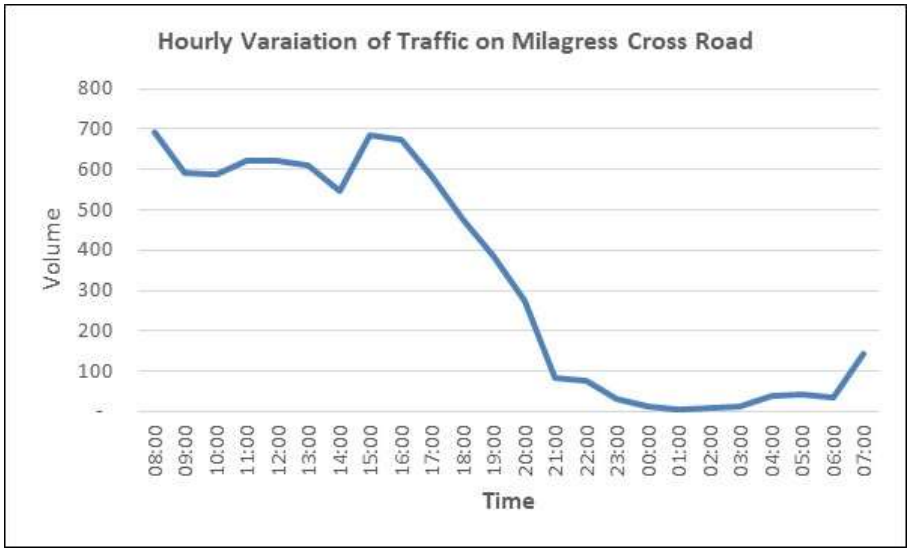
Cycle rickshaw	-	-	-	-	-
Animal Drawn	-	-	-	-	-
Hand Cart	-	-	-	-	-
Total Veh	**7,837**	**25,671**	**20,509**	**10,047**	**12,687**
Total PCU	**10,254**	**29,577**	**22,555**	**11,106**	**15,789**

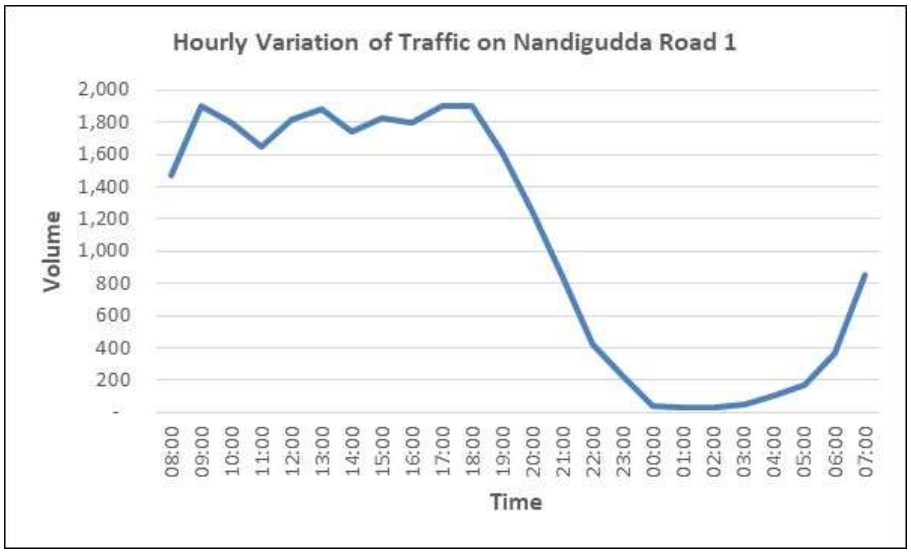
Traffic volume is highest on Jyoti Circle to Arya Samaj Junction at 87,138 PCU followed by Attavar-Nandigudda road 1 at 29,577 PCU followed by Attavar-Nandigudda Road 2 at 22,555 PCU. The detail of rest of the roads is given in the above table. Port road is carrying least traffic at 2,034 PCU.

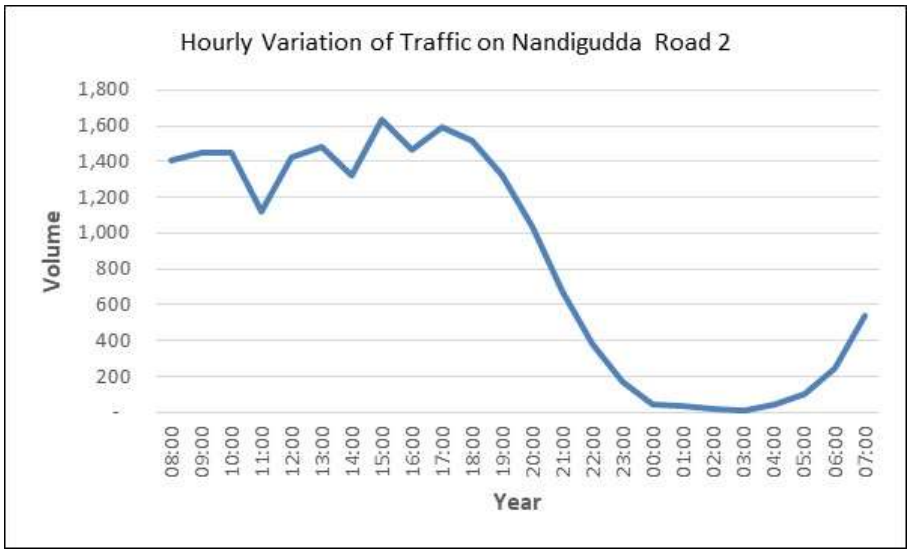
Since these are urban roads seasonal variations are minimal and, hence, ADT is considered as AADT.

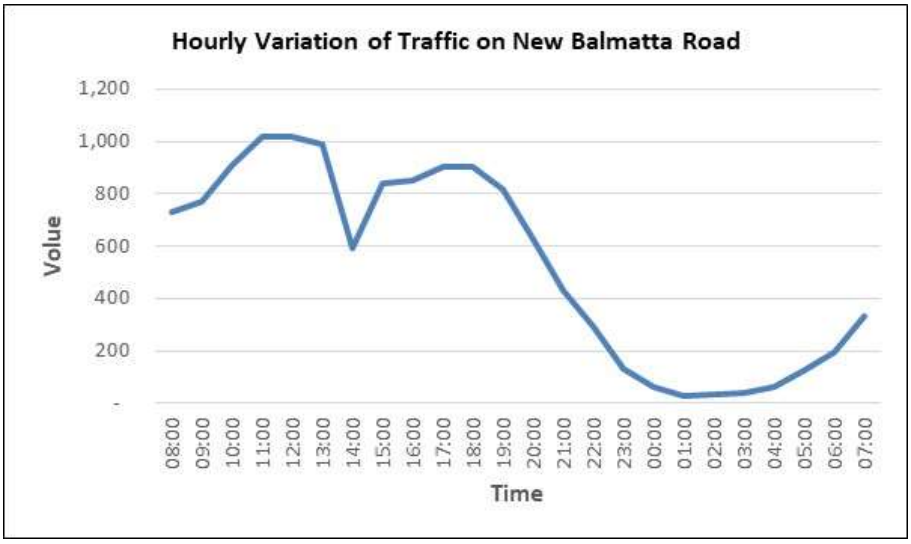
2.4.4.4 Hourly Variation

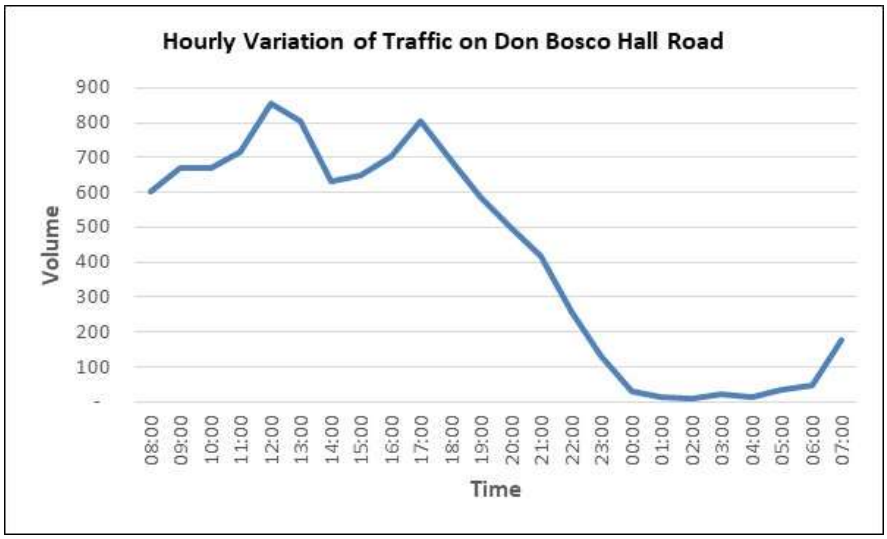
The hourly variation of traffic at survey locations is presented in following Figure .

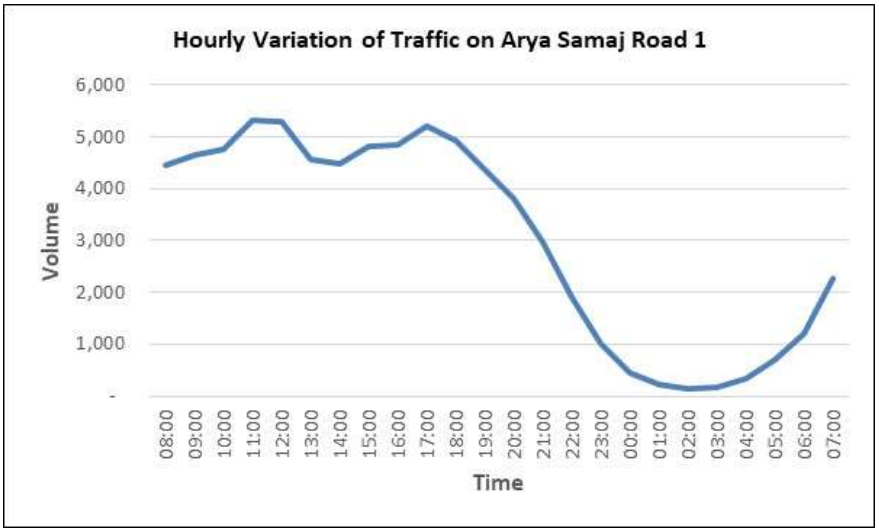


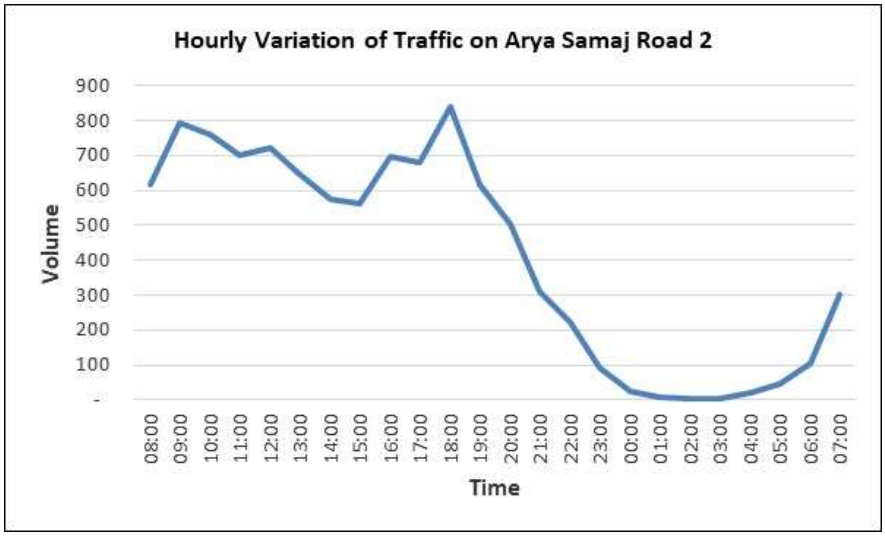

Hourly Variation of Traffic on Nandigudda Road 1
Volume
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time

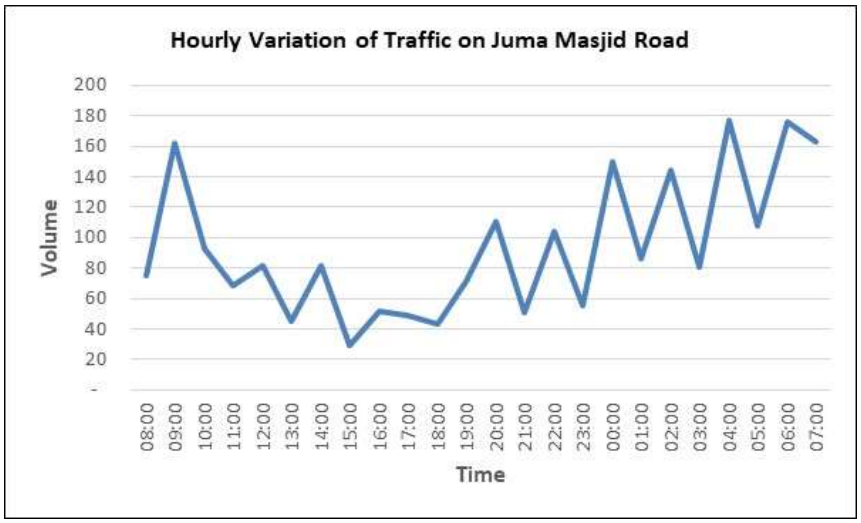

Hourly Variation of Traffic on Nandigudda Road 2
Volume
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Year

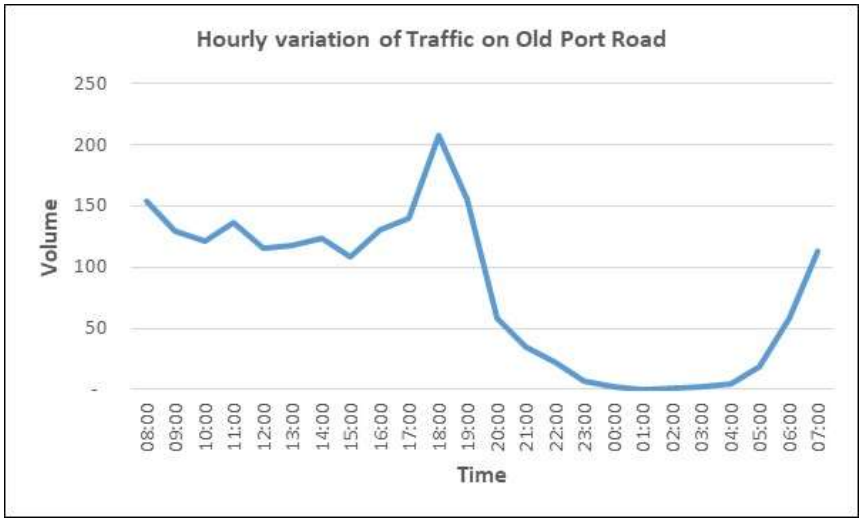

Hourly Variation of Traffic on New Balmatta Road
Volue
1,200
1,000
800
600
400
200
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time


Hourly Variation of Traffic on Don Bosco Hall Road
Volume
900
800
700
600
500
400
300
200
100
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time


Hourly Variation of Traffic on Arya Samaj Road 1
Volume
6,000
5,000
4,000
3,000
2,000
1,000
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time


Hourly Variation of Traffic on Arya Samaj Road 2
Volume
900
800
700
600
500
400
300
200
100
-
08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00
Time





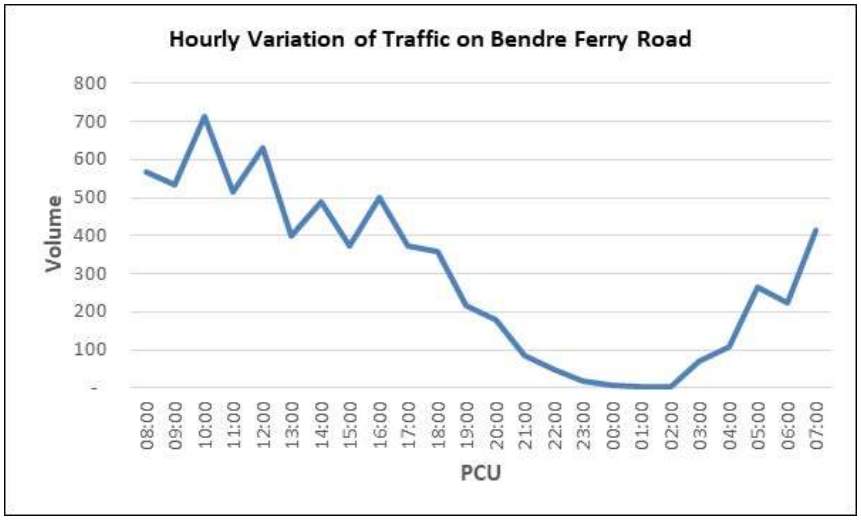


Figure 25 Hourly Variation Graphs of Traffic on DPR-5 Smart roads

2.4.4.5 Traffic Composition

The composition of traffic at the survey locations is presented in Following Figures.

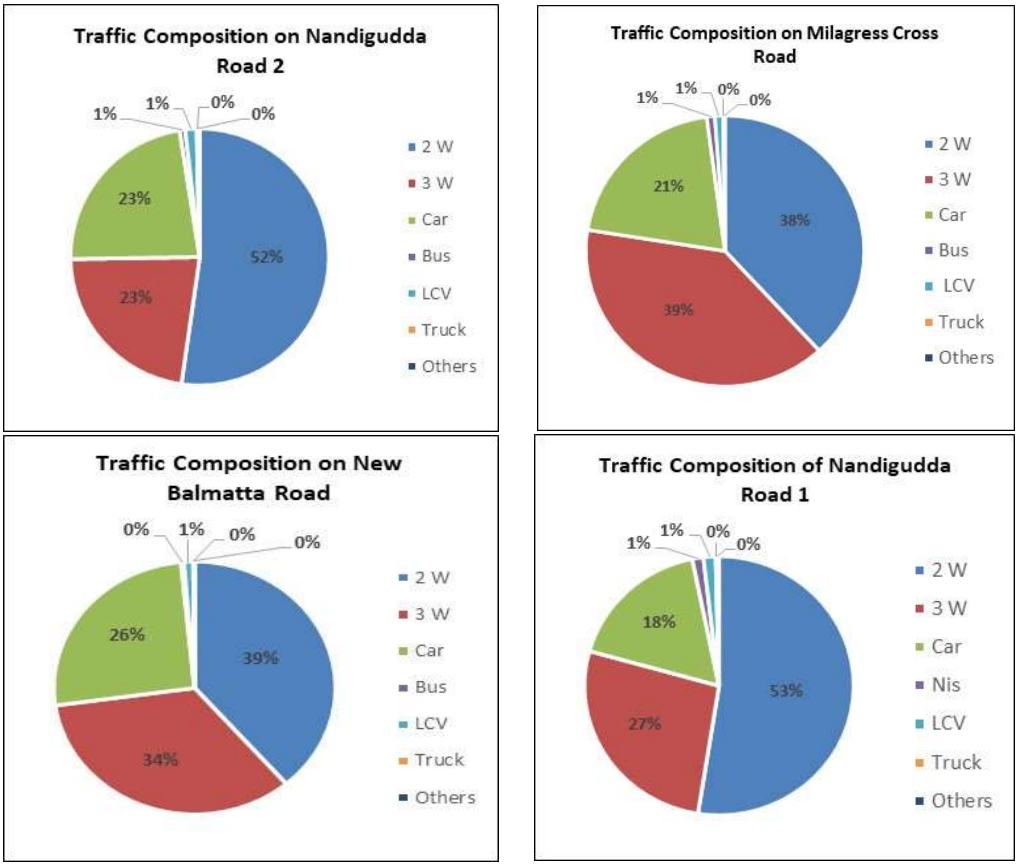


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Figure 26 Hourly Variation Graphs of Traffic on DPR-5 Smart roads

Traffic composition in terms of Passenger vehicles and Commercial vehicles is also analyzed to understand the impact of commercial vehicles and is presented in following tables.

Table 13 Composition of Passenger and Commercial Vehicles

Mode	Milagres Cross Road	Attavara-Nandigudda rd 1	Attavara Nandigudda rd 2	Don Bosco Hall Cross Road	New Balmatta Road
Passenger	99%	98%	98%	98%	99%
Commercial	1%	2%	2%	1%	1%

Mode	Arya Samaj Road	Jyothi Circle to Arya Samaj jn	Jumma Masjid Road	Port Road	Bengre Ferry Road
Passenger	99%	98%	94%	92%	89%
Commercial	1%	2%	3%	8%	10%

Mode	Milagres Cross Road	Attavara-Nandigudda rd 1	Attavara Nandigudda rd 2	Don Bosco Hall Cross Road	New Balmatta Road
Passenger	99%	99%	99%	100%	100%
Commercial	1%	1%	1%	0%	0%

Mode	Arya Samaj Road	Jyothi Circle to Arya Samaj jn	Jumma Masjid Road	Port Road	Bengre Ferry Road
Passenger	100%	93%	99%	100%	100%
Commercial	0%	7%	1%	0%	0%

Table 14 Composition of Public and Private modes of transport

The observations on the traffic and composition are:

- Passenger vehicles comprise about 92-99% of the total vehicles and commercial vehicles are meagre 1-2% except Port road and Bengre Ferry Road where the commercial vehicles are higher at 8-10%..
- Private vehicles are occupying the major portion of the urban road space. About 99%-100% of the vehicles except Jyothi Circle to Arya Samaj Junction are private vehicles and balance are public transport vehicles (mini bus+bus).

2.4.4.6 Peak Hour Analysis

In urban context, the roads are designed to cater to the requirements of peak hour volume. Hence, peak hour traffic analysis is done and presented in following tables

Table 15 Peak Hour Volume and Peak %age

Description	Milagres Cross Road	Attavara-Nandigudda rd 1	Attavara Nandigudda rd 2	Don Bosco Hall Cross Road	New Balmatta Road
Peak Hour	8:00-9:00 am	06:00-07:00 pm	03:00-04:00 pm	12:00-01:00 pm	12:00-01:00 pm
Peak, Vol	692	1,903	1,634	856	1,020
Peak,% (Vol)	8.83%	7.41%	7.97%	8.52%	8.04%
Peak, PCU	944	2,244	1,930	962	1,345
Peak,% (pcu)	9.20%	7.59%	8.56%	8.66%	8.52%

Description	Arya Samaj Road	Jyothi Circle to Arya Samaj jn	Jumma Masjid Road	Port Road	Bengre Ferry Road
Peak Hour	11:00-12:00 pm	06:00 – 07:00 pm	04:00 - 05:00 pm	10:00-11:00 am	09:00-10:00 am
Peak, Vol	5,335	839	177	713	713
Peak,% (Vol)	7.32%	8.52%	7.84%	10.04%	10.04%
Peak, PCU	6,638	875	173	723	723
Peak,% (pcu)	7.62%	8.40%	8.39%	9.88%	9.88%

The main junctions are falling on these selected roads, viz.,

1. Milagres Cross Road Junction
2. Anand Shetty Circle
3. Avery Junction
4. Arya Samaj Road Junction
5. Bombay Lucky Junction

Analysis of these junctions is carried out. The daily turning traffic volumes and PCU are presented at Figure 5-9.

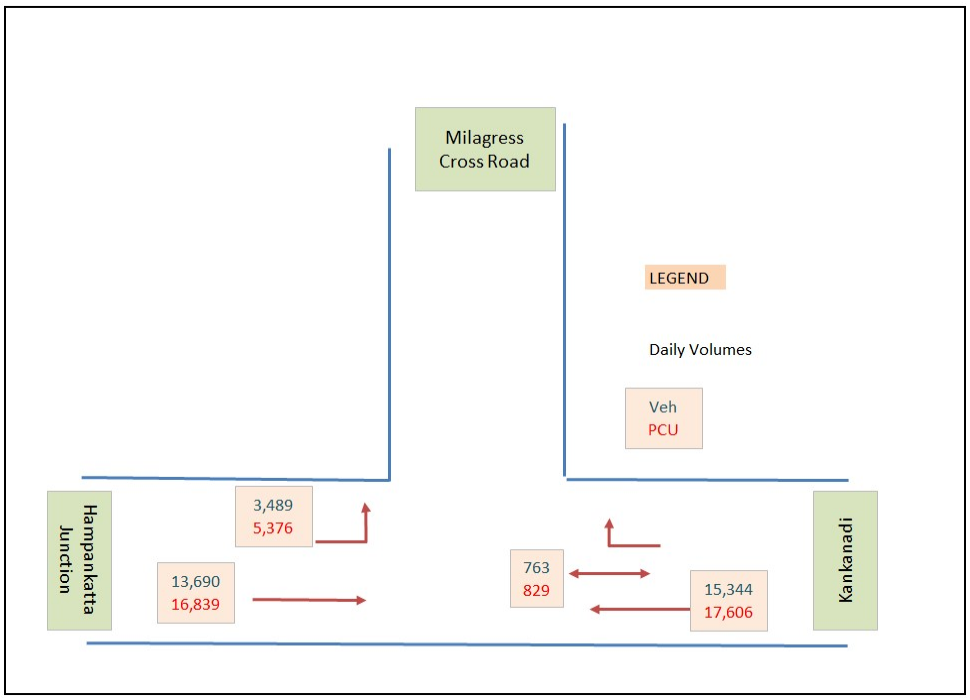

Figure 27: Milagres Cross Road Junction

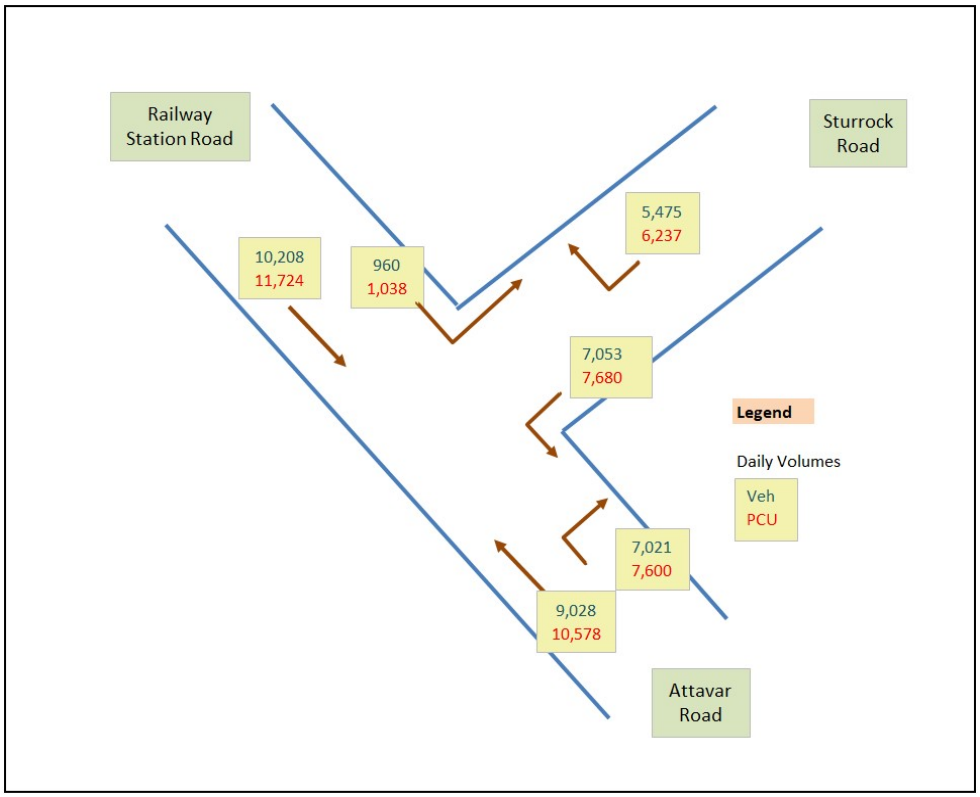

Figure 28: Anand Shetty Circle

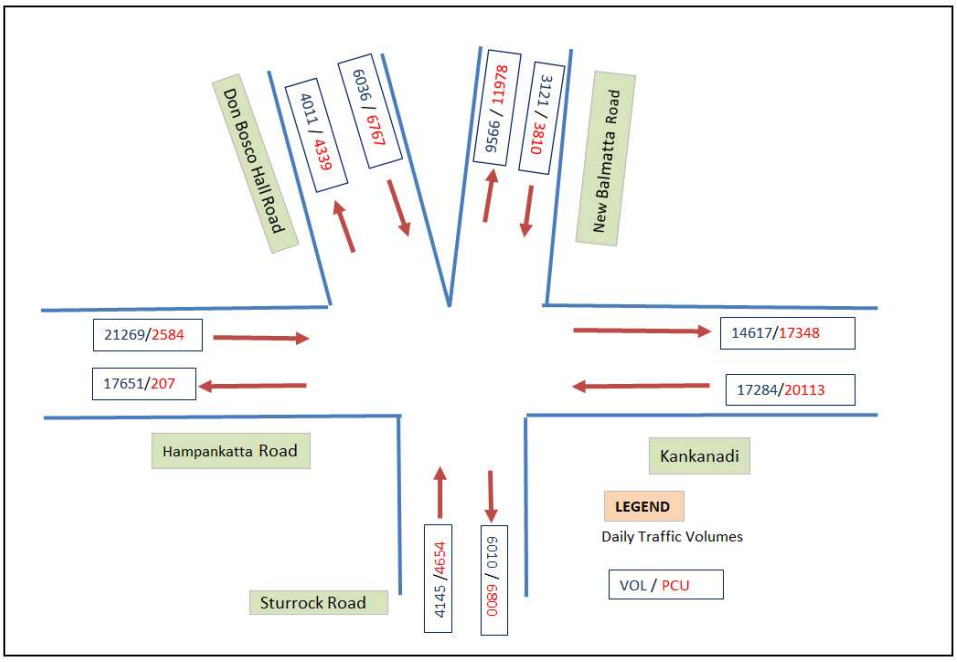

Figure 29: Avery Junction

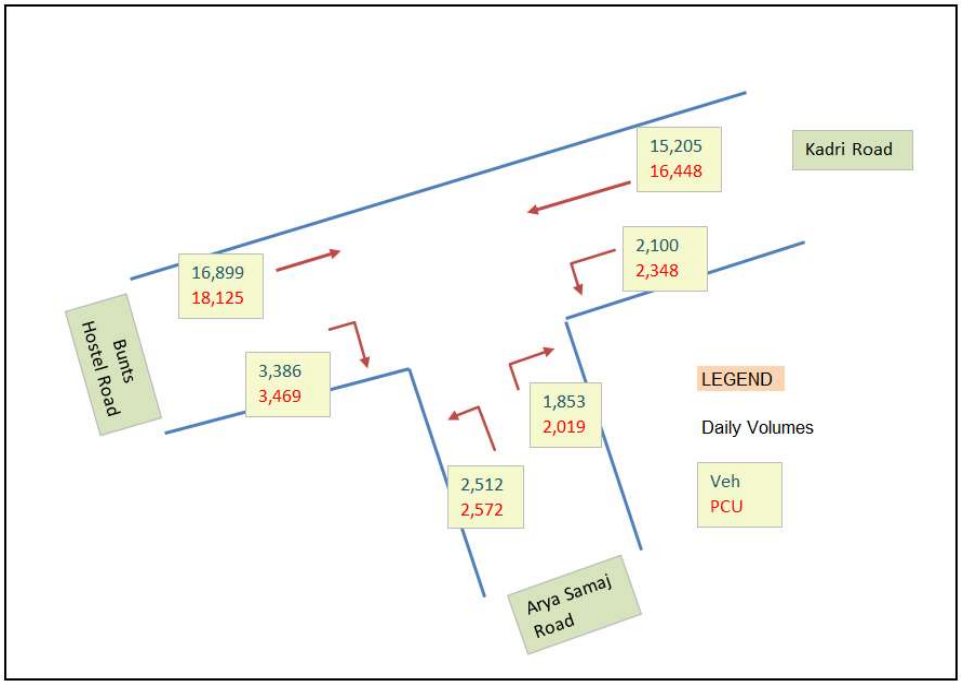

Figure 30: Arya Samaj Road Junction

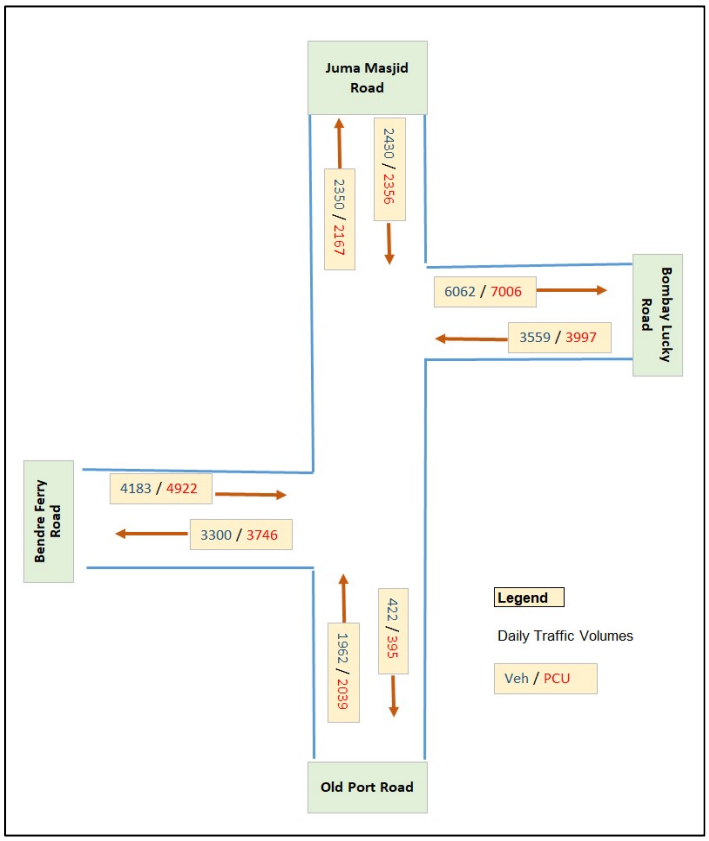

Figure 31: Bombay Lucky Junction

2.4.5 *Traffic Forecast*

Traffic Forecast in an Urban scenario is generally done through 4 stage travel demand modelling, which is an intensive exercise and is beyond the scope of this project. It is proposed to use growth rate to assess the capacity requirement of the selected roads. 3% growth rate is considered for the passenger vehicles and 2% is considered for the commercial vehicles. The projected peak hour PCU in different years is presented in Following tables:

Table 16 Projected Peak hour volumes in PCU

Year	Milagres Cross Road	Attavara-Nandigudda rd 1	Nandigudda Road 2	Don Bosco Hall Cross Road	New Balmatta Road
2018	944	2,244	1,930	962	1,345
2020	1,000	2,379	2,046	1,020	1,427
2025	1,157	2,753	2,370	1,180	1,653
2030	1,340	3,186	2,743	1,366	1,915
2035	1,551	3,686	3,177	1,582	2,218
2038	1,693	4,024	3,469	1,727	2,423

Year	Arya Samaj Road 1	Jyoti Circle to Arya Samaj Junction	Jama Masjid Road	Port Road	Bengre Ferry Road
2018	793	7,322	359	171	611
2020	841	7,747	381	181	646
2025	974	8,920	439	208	745
2030	1,128	10,275	508	239	857
2035	1,306	11,839	587	276	988
2038	1,426	12,890	640	301	1,075

Similarly, forecast was prepared for the Junctions and is presented in following table:

Table 17 Detailed Analysis of Junction Traffic for Present condition and Future Predictions (As per IRC -92)

S.No.	Junction Category	Name of Intersection	Peak Hour PCU (2018)	Peak Hour PCU (2028)	Peak Hour PCU (2038)	Year Grade separation warranted	Remarks
1	3 Leg	Milagres Cross Road Junction	3,654	4,910	6,599	Grade Separation not required	Junction Improvement along with road development
2	3 Leg	Anand Shetty Circle	3,581	4,812	6,467	Grade Separation not required	Junction Improvement along with road development
3	5 Leg	Avery Junction	5,475	7,357	9,887	Grade Separation not required	Junction Improvement along with road development
4	3 Leg	Arya Samaj Road Junction	3,539	4,757	6,394	Grade Separation not required	Junction Improvement along with road development
5	4 Leg	Bombay Lucky Junction	1,308	1,758	2,362	Grade Seperation not required.	Junction Improvement suggested

Table 18:Detailed Analysis of Junction as per SP-41

Junction Traffic Analysis			IRC SP 41 Criteria (Vehicle Per Day)					
S.NO.	Jn. Category	Name of Intersection	2018		2020		2025	
			Major Rd	Minor Rd	Major Rd	Minor Rd	Major Rd	Minor Rd
1	3 Leg	Milagres Cross Road Junction	29,034	8,600	30,772	9,120	35,590	10,564
2	3 Leg	Anand Shetty Circle	27,217	12,528	28,858	13,285	29,716	13,681
3	5 Leg	Avery Junction	44,011	7,844	46,653	8,319	53,978	9,636
4	3 Leg	Arya Samaj Road Junction	32,104	9,851	34,025	10,448	39,347	12,104
5	4 Leg	Bombay Lucky Junction	7,742	4,392	8,203	4,655	9,481	5,384

Junction Traffic Analysis			IRC SP 41 Criteria (Vehicle Per Day)					
S. NO.	Jn. Category	Name of Intersection	2028		2035		2038	
			Major Rd	Minor Rd	Major Rd	Minor Rd	Major Rd	Minor Rd
1	3 Leg	Milagres Cross Road Junction	38,837	11,537	47,620	14,173	51,971	15,480
2	3 Leg	Anand Shetty Circle	30,599	14,088	31,509	14,508	32,445	14,940
3	5 Leg	Avery Junction	58,916	10,525	72,277	12,930	78,897	14,123
4	3 Leg	Arya Samaj Road Junction	42,934	13,221	52,636	16,246	57,443	17,746
5	4 Leg	Bombay Lucky Junction	10,342	5,876	12,669	7,205	13,822	7,864

Similarly pedestrian vehicular conflict is analyzed and presented at Table 19.

Table 19: Pedestrian Vehicular Conflict at Major Arm

S.No.	Name of Intersection	Peak Hour	Arm	PV^2X10^8	Proposal
1	Milagres Cross Road	08:00 - 09:00 am	Milagres Cross Road	0.36	Control Measure
			Hampankatta Road	5.28	Control Measure
			Mother Theresa Road	10.72	Control Measure
2	Anand Shetty Circle	15:00-16:00 am	Railway Station Road	13.41	Control Measure
			Sturrock Road	5.91	Control Measure
			Attavar Road	23.93	Control Measure
3	Arya Samaj Junction	18:00 - 19:00 pm	Bunts Hostel Road	14.26	Control Measure
			Kadri Road	12.60	Control Measure
			Arya Samaj Road	1.10	Control Measure
4	Bomaby Lucky Junction	15:00-16:00	Bengre Ferry Road	0.24	Control Measure
			Jumma Masjid Road	0.16	Control Measure
			Bombay Lucky Road	0.38	Control Measure
			Old Port Road	0.02	Control Measure

2.4.6 Capacity Analysis

2.4.6.1 Road Standards

IRC:SP:106-1990– "Guidelines for Capacity of Urban Roads in Plains" specifies Design Service Volume of different urban roads and is given in following table:

Table 20 Recommended Design Service Volumes (PCU/Hr)

S.No.	Type of Carriageway	Total Design Service volumes for Different Catetories of Urban Roads		
		Arterial	Sub-arterial	Collector
1	2 Lane (One Way)	2,400	1,900	1,400
2	2 Lane (Two Way)	1,500	1,200	900
3	3 Lane (One Way)	3,600	2,900	2,200
4	4 Lane Undivided (Two Way)	3,000	2,400	1,800

5	4 Lane Divided (Two Way)	3,600	2,900	-
6	6 Lane Undivided (Two Way)	4,800	3,800	-
7	6 Lane Divided (Two Way)	5,400	4,300	-
8	8 Lane Divided (Two Way)	7,200	-	-

2.4.6.2 Junction Standards

IRC SP:41-1994, provides a graph for selection of intersection type based on traffic volumes which is reproduced in Figure 32for ready reference.

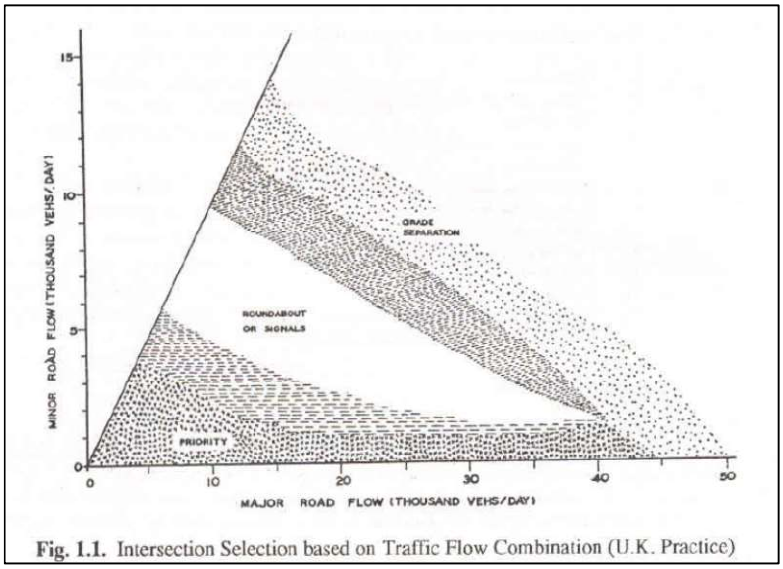

Fig. 1.1. Intersection Selection based on Traffic Flow Combination (U.K. Practice)

Figure 32: Intersection selection based on criteria

IRC-92-1985: An interchange may be justified when an **at-grade intersection fails to handle the volume of traffic** resulting in serious congestion and frequent choking of the intersection. This situation may arise when the **total traffic of all the arms of the intersection isin excess of 10,000 PCU/ hours.**

2.4.6.3 Pedestrian facilities

Intensity of pedestrians crossing the project road will decide the grade separators in the form of RUB, pedestrian crossing.

Pedestrian – vehicular conflict can be effectively studied through the indicator suggested in IRC:103-1988, Guidelines for Pedestrian facilities.

The code suggests some form of control measures at mid-blocks and intersections where the indicator PV^2 is greater than or equal to $2x10^8$ and for Zebra crossing PV^2 should be greater than $1x10^8$ where 'P' is the Peak hour pedestrian volume and 'V' is the number of vehicles in that peak hour.

2.4.6.4 Lane Configuration Analysis

A) Roads

The existing lane configuration of roads and capacity is presented at table below.

Table 21 Existing Lane Configuration of Roads

	Milagres Cross Road	Attavara-Nandigudda rd 1	Nandigudda Road 2	Don Bosco Hall Cross Road	New Balmatta Road
No of Lanes	2	2	2	2	2
Capacity	1,900	1,200	1,200	1,200	1,200

	Arya Samaj Road 1	Jyoti Circle to Arya Samaj Junction	Jama Masjid Road	Port Road	Bengre Ferry Road
No of Lanes	1,2	4	2	1,2	1,2
Capacity	1,200	3,600	1,200	1200	1200

The unconstrained capacity (lanes) requirement based on traffic analysis is given in table below. Please note that this is with the assumption that capacity enhancement is possible. Development strategy would be based on this capacity requirement and the feasibility of expansion, if possible.

Table 22 Unconstrained Capacity Requirement Based on Traffic (Lanes)

Year	Milagres Cross Road	Attavara-Nandigudda rd 1	Nandigudda Road 2	Don Bosco Hall Cross Road	New Balmatta Road
2018	2 L	4 L	4 L	2 L	4 L
2020	2 L	4 L	4 L	2 L	4 L
2025	2 L	4 L	4 L	2 L	4 L

2030	2 L	> 4 L	4 L	4 L	4 L
2035	2 L	> 4 L	> 4 L	4 L	4 L
2038	2 L	> 4 L	> 4 L	4 L	4 L

Year	Arya Samaj Road 1	Jyoti Circle to Arya Samaj Junction	Jama Masjid Road	Port Road	Bengre Ferry Road
2018	2 L	> 4 L	2 L	2 L	2 L
2020	2 L	> 4 L	2 L	2 L	2 L
2025	2 L	> 4 L	2 L	2 L	2 L
2030	2 L	> 4 L	2 L	2 L	2 L
2035	> 2 L	> 4 L	2 L	2 L	2 L
2038	> 2 L	> 4 L	2 L	2 L	2 L

From the above analysis, it can be seen that Milagres Cross Road, Jumma Masjid can operate with their existing lane configuration without any capacity augmentation in the horizon period. Rest of the roads are getting saturated and need capacity augmentation. However, this being a developed town space is a constraint.

B) Junctions

As per IRC 92 grade separation is not warranted as traffic at all the junctions is not more than 10,000 PCU/hr.

However as per IRC 41, grade separation is warranted if the traffic on major road crosses more than 45,000 vehicles and minor road traffic crosses more than 12,000 vehicles per day. Milagres Cross Road, Avery junction and Arya Samaj Road Junction get qualified for grade separation. However, space is a constraint. Considering this grade separation is recommended as and when space is available at these locations and for the time being improvement of the junctions is suggested.

2.4.6.5 Pedestrian facilities

Based on the analysis, at many locations the PV2 values are higher than 2x108 and hence mid-block and at junction control measures are suggested.

2.5 CARRIAGEWAY, JUNCTION IMPROVEMENT AND PAVEMENT DESIGN

2.5.1 Carriageway Improvement

2.5.1.1 Right of Way (ROW)

There are total of nine roads being improved in this phase namely:

1. Milagres Cross Rd.– From KMC Central Library Jn. to Milagres Church Jn.,
2. Attavara Nandigudda Rd.- From Nandigudda Wenlock Jn. to KMC Hospital,
3. New Balmatta Rd. – From Jyoti Circle to Avery Jn.,
4. Kudumbi Garden (DBS) Rd.- From KMC Mercara Trunk Rd to Avery Jn.,
5. Arya Samaj Rd. – From KRR Rd – Arya Samaj Rd Jn., and Balmatta Rd. Jn.,
6. Balmatta Rd. – From Jyoti Circle to KRR Rd – Arya Samaj Rd Jn.,
7. Azizuddin Rd. – From Car Street to Bunder Police Station,
8. Jumma Masjid-Old Port Rd. - From Car Street to Badria School Jn.
9. Bengre Ferry Rd. – From Jumma Masjid to BMS Ferry Lane.

Details of existing ROW are as follows:

1. Milagres Cross Rd. – Varies from 7.80m to 11.20m.
2. Attavara Nandigudda Rd. - Varies from 9.80m to 16.70m.
3. New Balmatta Rd. – Varies from 6.00m to 12.50m.
4. Kudumbi Garden (DBS) Rd.- Varies from 8.00m to 12.50m.
5. Arya Samaj Rd. – Varies from 6.40m to 10.60m.
6. Balmatta Rd. – Varies from 22.80m to 26.10m.
7. Azizuddin Rd. – Varies from 8.23m to 11.30m.
8. Jumma Masjid-Old Port Rd. - Varies from 4.51m to 6.75m.
9. Bengre Ferry Rd. – Varies from 5.61m to 12.95m.

MCC proposes to widen the streets, but it is not clear when this will happen. As per the discussion and confirmation with MSCL, the Consultants have prepared the proposals as per the existing RoW.

The following drawings enclosed in Annexure the Report provides details of Plan and Profile for DPR 5 roads

Table 23 Plan and Profile for DPR 5 roads

SN	Drawing no	Drawing Title	No of Sheets
1	WTE_2292_04_R_2.01	PLAN AND PROFILE OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	**1**

2	WTE_2292_04_R_2.02	PLAN AND PROFILE OF NEW BALMATTA ROAD (ROAD NO. 8)	**1**
3	WTE_2292_04_R_2.03	PLAN AND PROFILE OF ARYA SAMAJ ROAD (ROAD NO. 19a)	**1**
4	WTE_2292_04_R_2.04	PLAN AND PROFILE OF JUMMA MASJID OLDPORT ROAD (ROAD NO.15b)	**1**
5	WTE_2292_04_R_2.05	PLAN AND PROFILE OF BENGRE FERRY ROAD (ROAD NO.20)	**1**

2.5.1.2 Design Speed

Design speed is related to the function of a road. Keeping in view the type of functions expected on these roads, design speed has been considered as 40 to 50 Kmph for sub arterial roads & 30 km/h for distributor / Collector roads.

2.5.1.3 Cross Sections

Based on the traffic analysis and available ROW, it is proposed to develop these roads as follows:

1. Milagres Cross Road from KMC Central Library Junction to Milagres Church Junction is being developed as “2 Lane undivided carriageway which is being directed as one way traffic from KMC Central Library to Milagres Church Jn. (North to South)”. Lane width has been considered as 3.1 m. Raised footpaths are proposed on both sides wherever width of 1.00m or more is available.
2. Attavara Nandigudda Road from Nandigudda Wenlock Junction to KMC Hospital is being developed as "7.0m wide carriageway for bi-directional traffic with 3.5m lane width”. Raised footpaths are proposed on both sides considering the space availability; however the width of footpath varies depending on site constraints.
3. New Balmatta Road from Jyoti Circle to Avery Junction is being developed as “2 Lane two way single carriageway”. Lane width varies between 2.5m and 3.1 m. Raised footpaths are proposed on both sides wherever width of 1.00m or more is available.
4. Kudumbi Garden (DBS) Road from KMC Mercara Trunk Rd to Avery Junction is being developed as “2 Lane undivided carriageway with bi-directional traffic”. Lane width has been considered as 2.75 m. Raised footpaths are proposed on both sides wherever width of 1.00m or more is available.
5. Arya Samaj Road from KRR Road to Arya Samaj Road Junction and Balmatta Road Junction is being developed as “2 Lane undivided carriageway with 2.75m lane width has been proposed". Raised footpaths are proposed on both sides wherever width of 1.00m or more is available.
6. Balmatta Road from Jyoti Circle to KRR Road to Arya Samaj Road Junction is being developed as "4 lane two directional divided carriageway". Lane width has been considered as 3.5m. Raised footpath is proposed on both sides considering the space availability.
7. Azizuddin Road from Car Street to Bunder Police Station is being developed as "2 lane undivided carriageway with bi-directional traffic". Lane width has been considered as 2.75m. Raised footpath is proposed on both sides considering the space availability.

8. Jumma Masjid-Old Port Road from Car Street to Badria School Junction is being developed as "2 lane undivided carriageway with bi-directional traffic". Lane width has been considered as 2.75m. No Raised footpath has been proposed due to minimal space availability.
9. Bengre Ferry Road from Jumma Masjid to BMS Ferry Lane including 4 different sections as below
   - Two lane undivided carriageway with bi-directional traffic from CH. KM. 0+000 to 0+100 and 0+210 to 0+250" with lane width of 2.75m. Raised footpath is proposed on one side of the carriageway.
   - From CH. KM. 0+100 to 0+210 the road is being developed as "2 lane undivided carriageway with bi-directional traffic" with lane width of 2m. No Raised footpath has been proposed due to minimal space availability.
   - From CH. KM. 0+250 to 0+700 the road is being developed as "2 lane undivided carriageway with bi-directional traffic" with lane width of 3.5m. Raised footpath is proposed on one side of the carriageway.
   - From CH. KM 0+700 to 1+050 the road is being developed as "2 lane undivided carriageway with bi-directional traffic" with lane width of 5.0m. Raised footpath is proposed on one side of the carriageway.

2.5.1.4 Camber / Cross Fall

The existing camber is retained for the CC roads and where new CC roads are being developed a camber of 2.5% is being provided.

2.5.1.5 Geometry / Alignment

Geometric design & Alignment design has been done in accordance with MoUD and IRC guidelines.

2.5.2 Intersection Improvement

Road intersections are critical element of road section. They are normally a major bottleneck to smooth flow of traffic and a major accident spot. Function of a designed intersection is to control conflicting and merging streams of traffic, to minimize the delay including pedestrian traffic.

Intersection design influences the capacity of the corridor and the safe movement of conflicting directions. The pattern of the traffic movements at the intersection and the volume of traffic on each approach, during peak period of the day determine the lane widths required.

The general design principles of intersection design are the approach speeds, restriction on available land, sight distance available and the presence of the larger volume of all the road users in urban areas.

2.5.2.1 Function of Intersection Design

The function of an intersection is to enable safe interchange between two directions or two modes.

The aim of the design of an intersection is to achieve with a minimum number of conflict points while following the basic principle to limit the number of conflict points between cars, buses, trucks, bicycles and the pedestrians as much as possible.

2.5.2.2 Classification of Intersections types

Intersection functions to control conflicting and merging traffic and to achieve this, intersections are designed on certain geometric parameters and are broadly classified into three main heads and are as follows:

- Un signalized intersection,
- Signalized Intersection and
- Roundabouts

A) Un-signalized intersection: There are two types of un-signalized intersections:

- Uncontrolled Intersection: These are the intersections between any two roads with relatively lower volume of traffic and traffic of neither road has precedence over the other.
- Intersection with Primary Control: In this type there are theoretically no delay occurring on the major road and vehicles on the minor road are controlled by 'GIVE WAY' or 'STOP' signs and marking

B) Signalized Intersection:

Signalization is applied at junctions where higher motorized vehicle volumes require control by traffic lights. Traffic movement of different arms entering the intersection is controlled by traffic lights.

C) Roundabouts:

A roundabout is an intersection with a central island around which traffic must travel clockwise and in which entering traffic must 'GIVE WAY' to circulating traffic.

Table below depicts the Pros and Cons of type of Intersection Lane Requirement

Table 24 Pros and Cons of Signalized Intersection and Roundabout

Signalized Intersection	Roundabout
Pros	
Signalized intersection can handle high traffic volumes	Reduces number of conflicts
Safety is ensured by eliminating conflicts through signalization	Ensures safety through speed reduction by design
	Minimum delays for all road users
Cons	
Higher delays for all road users	Roundabouts are not very effective for more than two circulatory lanes
	Roundabouts have capacity limitations and may not be able to handle a very high volume of traffic.

2.5.2.3 Objectives for Intersection Design

The main objective of intersection design is to facilitate the convenience, ease and comfort of people traversing the intersection while enhancing the efficient movement of passenger cars, buses, trucks, bicycles and pedestrians. The need for flexibility dictates the choice of the most suitable intersection type.

2.5.2.4 Consideration for Intersection Design

Design of a safe intersection depends on following major factors:

- Design and actual capacities
- Design hourly traffic turning movements
- Variety of movements
- Vehicle Speeds
- Pedestrian movements
- Geometric features
- Traffic control devices
- Cost of improvements
- Energy consumption

2.5.2.5 Design Traffic Volumes:

Intersections are normally designed for peak hour flows. Turning movement count has been carried out and the data has been used after estimation of future traffic for intersection design.

2.5.2.6 Capacity of Intersections:

Intersection capacity is the maximum hourly rate at which vehicles can reasonably be expected to pass through the intersection under prevailing traffic, roadway and signalized conditions. Capacity is influenced by traffic and roadway conditions. Traffic conditions includes volumes on each approach, the distribution of vehicles on each arm of intersection, the vehicle types distribution within each movement, pedestrian traffic flows and parking movements on approaches to the intersection.

Traffic control at intersections limits the capacity of the intersecting roadways, defined as the number of users that can be accommodated within a given time period. Capacity of an intersection depends on the following factors:

- Physical and operating conditions like width of approach, one way or two way operation and parking conditions etc.
- Traffic characteristics like turning movements, number of commercial vehicles including buses, peak hour factors, number of pedestrians and geometry.

As per IRC: SP: 41-1994 "Guidelines on Design of At-Grade Intersections in Rural & Urban Areas", the intersection capacity is 700 to 1200 PCU's per hour per lane for one way traffic and 450 to 750 PCU's for two way traffic.

2.5.2.7 Traffic Calming Techniques

Traffic calming and speed management measures such as road humps are considered to discouraging traffic from entering intersection areas with high speed. These measures are always backed up by speed limits of 30 km/hr or less. Management of speed by engineering the road with the purpose to bring the design of the road in accordance with the desired speed is called speed management by design or traffic calming.

Trapezoidal Humps and Raised Pedestrian Crossing (Table Top)

A hump, which constitutes 150 mm, raised, flat section of a carriageway with ramps on both sides is called a trapezoidal hump. Trapezoidal humps can be used as pedestrian crossings.

- Since there is no negotiation in change of level, it improves walking and makes it more comfortable and convenient to the pedestrians.
- Makes the pedestrian alert and safe from entering and exiting vehicles.
- It gives the utmost comfort to people with disability and follows the concept of universal design.

2.5.3 Pavement Design

2.5.3.1 Arya Samaj Road

Road Type: Four lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 6270 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 8.0% and 7.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 25 Axial load Spectrum assumed – Arya Samaj Road

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

A. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.
- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)

- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

B. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

C. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

  $C = 365 \times A ((1 + r)^n - 1) / r$

  Where,

  C –Cumulative number of commercial vehicles during the design period

  A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

  r – Annual rate of growth of commercial traffic volume (in decimal)

  n – Design period in years

  $C = 365 \times 6270((1+0.05)^{30}-1)/0.05$

  $C= 152048624$

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

  $= 152048624 \times 2.35$

  $= 357314267$

- No. of axles in predominant direction

  $= 357314267 \times 0.5$

  $= 178657134$

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  $= 21740892 \times 0.25$

= 44664283

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 44664283 X 0.6

  = 26798570

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 44664283 X 0.4

  =17865713

- Day time six hour axle load repetitions

  = 17865713 X 0.5

  = 8932857

  Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **8932857**

- Night time six hour axle load repetitions

  = 26798570 X 0.5

  = 13399285

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 13399285 X 0.55

  = **7369607**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 26 Fatigue Cracking Analysis

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	3316323	4019786
Rear single	0.53	3905892	4734414
Tandem	0.02	147392	178657

D. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^0C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^0C
- Trial thickness of slab, h = 235 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.55556

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	781178	2.41	0.487	1534711	0.509	220 - 240	132653	1.94	0.391	Infinite	0.000
105-115	390589	2.29	0.462	1177418	0.332	200 - 220	14739	1.82	0.368	Infinite	0.000
95-105	781178	2.16	0.460	Infinite	0.00						
< 85	1952946	1.91	0.386	Infinite	0.000						
	489170	Fat Dam from Sing. Axles =			0.841		21741	Fat Dam from Tand Axles =			0.000

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	946883	2.31	0.466	7279255	0.000	220 - 240	160791	2.27	0.458	19180086	0.000
105-115	473441	2.22	0.449	Infinite	0.000	200 - 220	17866	2.18	0.440	Infinite	0.000
95-105	946883	2.14	0.432	Infinite	0.000						
< 85	2367207	1.96	0.397	Infinite	0.000						
	475310	Fat Dam from Sing. Axles =			0.130		21741	Fat Dam from Tand Axles =			0.008

It can be seen from the calculations given in the tables above that for the slab thickness of 235mmthe total fatigue damage for bottom-up cracking is 0.841 + 0.000 = 0.841. Total fatigue damage for top-down cracking is 0.130 + 0.008 = 0.138 and total cumulative fatigue damage (CFD) = 0.979 which is less than 1.0.

Hence, the trial thickness of 235mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 280mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.280 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa -200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.280X24000/200

=156.2 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/156.2X1000

  = 723 mm

  Say 750mm

- Provide spacing of 750mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 27 Pavement Composition

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	280
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.2 Arya Smaj Road 2

Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Two lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 144 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 5.0% and 6.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 28 Axle Load Spectrum (Assumed) – Arya Samaj Road 2

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

E. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

F. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

G. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

  $C = 365 \times A ((1 + r)^n – 1) / r$

  Where,

  C –Cumulative number of commercial vehicles during the design period

  A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

  r – Annual rate of growth of commercial traffic volume (in decimal)

  n – Design period in years

  $C = 365 \times 144((1+0.05)^{30}-1)/0.05$

  C= 3492026

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

  = 6062545 X 2.35

  = 8206261

- No. of axles in predominant direction

  = 8206261 X 0.5

  = 4103130

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  =4103130X 0.25

  = 1025783

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 1025783 X 0.6

  = 615470

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 1025783 X 0.4

  =410313

- Day time six hour axle load repetitions

  = 410313 X 0.5

  = 205157

- Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **205157**

- Night time six hour axle load repetitions

  = 615470 X 0.5

  = 307735

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 307735 X 0.55

  = **169254**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 29 fatigue cracking analysis – Arya Samaj Road 2

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	92321	76164
Rear single	0.53	108733	89705
Tandem	0.02	4103	3385

H. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 205 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.55556

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 30 Fatigue Damage Analysis – Arya Samaj Road 2

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	21747	2.784	0.562	87857	0.248	220 - 240	3693	2.267	0.458	18320259	0.000
105-115	10873	2.633	0.532	214376	0.051	200 - 220	410	2.131	0.431	infinite	0.000
95-105	21747	2.483	0.502	707338	0.031						
< 85	54367	2.181	0.441	infinite	0.000						
	108733	Fat Dam from Sing. Axles =			0.329		4103	Fat Dam from Tand Axles =			0.000

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	17941	2.593	0.524	284225	0.063	220 - 240	3047	2.541	0.513	423020	0.007
105-115	8970	2.489	0.503	665309	0.013	200 - 220	339	2.437	0.492	1125609	0.000
95-105	17941	2.386	0.482	2107060	0.009						
< 85	44852	2.179	0.440	infinite	0.000						
	155737	Fat Dam from Sing. Axles =			0.085		5877	Fat Dam from Tand Axles =			0.007

It can be seen from the calculations given in the tables above that for the slab thickness of 205mmthe total fatigue damage for bottom-up cracking is 0.329 + 0.000 = 0.329. Total fatigue damage for top-down cracking is 0.085 + 0.007 = 0.092 and total cumulative fatigue damage (CFD) = 0.421 which is less than 1.0.

Hence, the trial thickness of 205mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 250mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.205 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa - 200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.205X24000/200

=114.39 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/114.39X1000

  = 989 mm

  Say 950mm

- Provide spacing of 950mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 31 Pavement Composition: Arya Samaj Road 2

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	250
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.3 Bengre Ferry Road 1

Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Four lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 741 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 8.0% and 7.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 32 Axle Load Spectrum (Assumed): Bengre Ferry Road 1

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

I. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

J. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

K. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

$C = 365 \times A ((1 + r)^n – 1) / r$

Where,

C –Cumulative number of commercial vehicles during the design period

A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

r – Annual rate of growth of commercial traffic volume (in decimal)

n – Design period in years

$C = 365 \times 741((1+0.05)^{30}-1)/0.05$

C= 17969383

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

= 18502887 X 2.35

= 42228050

- No. of axles in predominant direction

= 42228050 X 0.5

= 21114025

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  = 21114025 X 0.25

  = 5278506

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 5278506 X 0.6

  =3167104

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  =5278506X 0.4

  =2111403

- Day time six hour axle load repetitions

  = 2111403 X 0.5

  = 1055701

  Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **1055701**

- Night time six hour axle load repetitions

  = 1055701 X 0.5

  = 527850

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 527850 X 0.55

  = **290317**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 33 Fatigue Cracking Analysis Axle -Bengre Ferry Road 1

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	475065	130643
Rear single	0.53	559522	153868
Tandem	0.02	21114	5806

L. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 225 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.574

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 34 Fatigue Damage Analysis: Bengre Ferry Road 1

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	111904	2.55	0.516	385306	0.290	220 - 240	19003	2.06	0.416	Infinite	0.000
105-115	55952	2.42	0.488	1446409	0.039	200 - 220	2111	1.94	0.391	Infinite	0.000
95-105	111904	2.28	0.460	13839398	0.008						
< 85	279761	2.00	0.405	Infinite	0.000						
	559522	Fat Dam from Sing. Axles =			0.337		21114	Fat Dam from Tand Axles =			0.000

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	30774	2.40	0.486	1653498	0.068	220 - 240	5226	2.36	0.476	3144238	0.001
105-115	15387	2.31	0.467	7003190	0.008	200 - 220	581	2.26	0.457	20274736	0.000
95-105	30774	2.22	0.448	Infinite	0.000						
< 85	76934	2.03	0.410	Infinite	0.000						
	153868	Fat Dam from Sing. Axles =			0.076		5806	Fat Dam from Tand Axles =			0.001

It can be seen from the calculations given in the tables above that for the slab thickness of 225mmthe total fatigue damage for bottom-up cracking is 0.337 + 0.000 = 0.337. Total fatigue damage for top-down cracking is 0.076 + 0.001 = 0.077 and total cumulative fatigue damage (CFD) = 0.414 which is less than 1.0.

Hence, the trial thickness of 225mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 270mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.280 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa -200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.270X24000/200

=151.07 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/151.0X1000

  = 748 mm

  Say 750mm

- Provide spacing of 750mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 35 Pavement Composition: Bengre Ferry Road 1

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	270
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.4 Milagres Cross Road

Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Two lanesOne Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 161 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 9.0% and 8.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 36 Axle Load Spectrum (Assumed): Milegres Cross Road

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		100%		100%

Design:

M. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

N. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

O. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- One way commercial traffic volume per day =169 CVPD
- Total commercial vehicles during design period

  $C = 365 X A ((1 + r)^n – 1) / r$

  Where,

  C –Cumulative number of commercial vehicles during the design period

  A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

  r – Annual rate of growth of commercial traffic volume (in decimal)

  n – Design period in years

  $C = 365 X 161((1+0.05)^{30}-1)/0.05$

  C= 3904279

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

  = 4098280 X 2.35

  =9175055

- No. of axles in predominant direction

  = 9175055 X 1 (One Way Traffic)

  = 9175055

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  = 9175055 X 0.25

  = 1146882

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 1146882 X 0.6

  = 688129

  Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 1146882 X 0.4

  =458753

- Day time six hour axle load repetitions

  = 458753 X 0.5

  = 229376

- Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **229376**

  Night time six hour axle load repetitions

  = 688129 X 0.5

  = 344065

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 344065 X 0.55

  = **189236**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 37 Fatigue cracking analysis

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	103219	85156
Rear single	0.53	121569	100295
Tandem	0.02	4588	3785

P. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 205 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.55556

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 38 Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	20644	2.784	0.562	87857	0.23	220 - 240	4129	2.267	0.458	18320259	0.001
105-115	10322	2.633	0.532	214376	0.05	200 - 220	458	2.131	0.431	infinite	0.000
95-105	20644	2.483	0.502	707338	0.03						
< 85	51610	2.181	0.441	infinite	0.000						
	103220	Fat Dam from Sing. Axles =			0.380		9631	Fat Dam from Tand Axles =			0.001

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	20059	2.784	0.562	87857	0.23	220 - 240	3406	2.267	0.458	18320259	0.000
105-115	10030	2.633	0.532	214376	0.05	200 - 220	378	2.131	0.431	infinite	0.000
95-105	20059	2.483	0.502	707338	0.03						
< 85	50148	2.181	0.441	infinite	0.000						
	100295	Fat Dam from Sing. Axles =			0.310		5877	Fat Dam from Tand Axles =			0.000

It can be seen from the calculations given in the tables above that for the slab thickness of 205mmthe total fatigue damage for bottom-up cracking is 0.380 + 0.001 = 0.381. Total fatigue damage for top-down cracking is 0.310 + 0.000 = 0.310 and total cumulative fatigue damage (CFD) = 0.690 which is less than 1.0.

Hence, the trial thickness of 205mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 250mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.205 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa - 200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.205X24000/200

=114.39 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/114.39X1000

  = 989 mm

  Say 950mm

- Provide spacing of 950mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 39 Pavement Composition:

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	250
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.5 Nadigudda Road- 1

Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Four lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 763 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 8.0% and 7.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 40 Axle Load Spectrum (Assumed): Nadiguda road 1

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

Q. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

R. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

S. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

$C = 365 \times A ((1 + r)^n – 1) / r$

Where,

C –Cumulative number of commercial vehicles during the design period

A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

r – Annual rate of growth of commercial traffic volume (in decimal)

n – Design period in years

$C = 365 \times 763((1+0.05)^{30}-1)/0.05$

C= 18502887

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

= 18502887 X 2.35

= 43481784

- No. of axles in predominant direction

= 43481784 X 0.5

= 21740892

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  = 21740892 X 0.25

  = 5435223

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 5435223 X 0.6

  = 3261134

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 5435223 X 0.4

  =2174089

- Day time six hour axle load repetitions

  = 2174089 X 0.5

  = 1087045

  Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **1087045**

- Night time six hour axle load repetitions

  = 3261134 X 0.5

  = 1630567

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 1630567 X 0.55

  = **896811**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 41 fatigue cracking analysis – Nadiguda Road 1

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	489170	403565
Rear single	0.53	576134	475310
Tandem	0.02	21741	17936

T. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 225 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.574

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 42 Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	115227	2.55	0.516	385306	0.299	220 - 240	19567	2.06	0.416	Infinite	0.000
105-115	57613	2.42	0.488	1446409	0.040	200 - 220	2174	1.94	0.391	Infinite	0.000
95-105	115227	2.28	0.460	13839398	0.008						
< 85	288067	2.00	0.405	Infinite	0.000						
	576134	Fat Dam from Sing. Axles =			0.347		21741	Fat Dam from Tand Axles =			0.000

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	95062	2.40	0.486	1653498	0.057	220 - 240	16143	2.36	0.476	3144238	0.005
105-115	47531	2.31	0.467	7003190	0.007	200 - 220	1794	2.26	0.457	20274736	0.000
95-105	95062	2.22	0.448	Infinite	0.000						
< 85	237655	2.03	0.410	Infinite	0.000						
	475310	Fat Dam from Sing. Axles =			0.064		21741	Fat Dam from Tand Axles =			0.005

It can be seen from the calculations given in the tables above that for the slab thickness of 225mmthe total fatigue damage for bottom-up cracking is 0.347 + 0.000 = 0.347. Total fatigue damage for top-down cracking is 0.064 + 0.005 = 0.069 and total cumulative fatigue damage (CFD) = 0.416 which is less than 1.0.

Hence, the trial thickness of 225mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 270mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.280 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa -200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.270X24000/200

=151.07 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/151.0X1000

  = 748 mm

  Say 750mm

- Provide spacing of 750mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 43 Pavement Composition:

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	270
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.6 Nadiguda Road- 2

-Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Two lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 461 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 8.0% and 7.0%.

CBR (Considered) of Proposed Subgrade: 8%

CBR (Assumed) of Embankment below subgrade: 8%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 44 Axle Load Spectrum (Assumed): Nadiguda road 2

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

U. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

V. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

W. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

$C = 365 \times A ((1 + r)^n – 1) / r$

Where,

C –Cumulative number of commercial vehicles during the design period

A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

r – Annual rate of growth of commercial traffic volume (in decimal)

n – Design period in years

$C = 365 \times 461((1+0.05)^{30}-1)/0.05$

C= 11179333

- Average number of axles (steering / single / tandem) per commercial vehicle =2.35
- Total two way axle load repetitions during the design period –

= 11179333 X 2.35

= 26271432

- No. of axles in predominant direction

=26271432 X 0.5

= 13135716

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  = 13135716 X 0.25

  = 3283929

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 3283929 X 0.6

  = 1970357

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 3283929 X 0.4

  =1313572

- Day time six hour axle load repetitions

  = 1313572 X 0.5

  = 656786

  Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **656786**

- Night time six hour axle load repetitions

  =1970357X 0.5

  = 985178

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 985178 X 0.55

  = **541848**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 45 Fatigue cracking analysis

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	295554	243832
Rear single	0.53	348096	287180
Tandem	0.02	13136	10837

X. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 215 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.55556

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 46 Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	69619	2.72	0.549	129260	0.539	220 - 240	11822	2.20	0.444	3855797	0.003
105-115	34810	2.57	0.518	349050	0.100	200 - 220	1314	2.06	0.417	Infinite	0.000
95-105	69619	2.41	0.488	1464737	0.048						
< 85	174048	2.11	0.427	Infinite	0.000						
	348096	Fat Dam from Sing. Axles =			0.686		21741	Fat Dam from Tand Axles =			0.003

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	57436	2.52	0.508	525380	0.109	220 - 240	11822	2.41	0.487	1513165	0.007
105-115	28718	2.41	0.487	1513165	0.019	200 - 220	1314	2.36	0.477	3026279	0.000
95-105	57436	2.31	0.466	7302230	0.008						
< 85	143590	2.10	0.424	Infinite	0.000						
	475310	Fat Dam from Sing. Axles =			0.136		21741	Fat Dam from Tand Axles =			0.007

It can be seen from the calculations given in the tables above that for the slab thickness of 235mmthe total fatigue damage for bottom-up cracking is 0.686 + 0.003 = 0.689. Total fatigue damage for top-down cracking is 0.136 + 0.007 = 0.043 and total cumulative fatigue damage (CFD) = 0.732 which is less than 1.0.

Hence, the trial thickness of 215mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 260mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.260 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa - 200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.260X24000/200

=145.1 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/145.1X1000

  = 778 mm

  Say 780mm

- Provide spacing of 750mm c/c

- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 47 Pavement Composition:

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	260
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.5.3.7 New Balmatta Road

Design of Plain Jointed Rigid Pavement

Design of Slab Thickness

Input Data:

Road Type: Two lanes Two Way Single Carriageway

Design Life: 30 Years

Lane Width: 3.1m with 0.25m shyness width on both sides of carriageway edge.

Transverse joint spacing: 4.5 m

Traffic (as per TVC): 196 Commercial Vehicles per Day (CVPD)

CBR of Existing Soil: Two samples collected and tested and are 6% and 5%.

CBR (Considered) of Proposed Subgrade: 6%

CBR (Assumed) of Embankment below subgrade: 6%

Effective CBR of Subgrade: 8% (As per Figure 2 of IRC 58-2015)

Axle load Survey (Assumed): Single Axle 98% and Tandem Axle 2%

Table 48 Axle Load Spectrum (Assumed):

Sr. No.	Rear Single Axle		Rear Tandem Axle	
	Axle Load KN	Frequency (% of single Axles)	Axle Load KN	Frequency (% of tandem Axles)
1	115-125	20	220-240	90
2	105-115	10	200-220	10
3	95-105	20		
4	< 85	50		
Total		98%		2%

Design:

Y. Modulus of Subgrade Reaction:

- Effective CBR of compacted subgrade = 8%. Modulus of subgrade reaction = 50.3 MPa/m (from Table 2 of IRC 58-2015)
- Provide 150mm thick Granular Sub-Base as drainage layer (Grading VI of Table 400-1 of MoRTH Specifications Fifth Revision)
- Provide a Dry Lean Concrete (DLC) sub-base of thickness 100mm with a minimum 7 day compressive strength of 10 MPa.

- Effective modulus of subgrade reaction of combined foundation of subgrade, granular sub-base and DLC sub-base is 231.3 MPa/m (from Table 4 of IRC 58-2015 by interpolation)
- Provide a de-bonding layer of polythene sheet of 125 micron thickness between DLC and concrete slab.

Z. Flexural Strength of Concrete

- 28 day compressive strength of cement concrete ≥ 40 MPa
- 90 day compressive strength of cement concrete ≥ 48 MPa
- 28 day Flexural strength of cement concrete = 4.5 MPa (minimum)
- 90 day Flexural strength of cement concrete = 4.5 X 1.1 = 4.95 MPa

AA. Design Traffic for Fatigue Analysis

- Design Period – 30 years
- Assumed Annual rate of growth of commercial traffic = 5 %
- Total commercial vehicles during design period

$C = 365 \times A ((1 + r)^n – 1) / r$

Where,

C –Cumulative number of commercial vehicles during the design period

A – Initial number of commercial vehicles per day in the year when the road is opened to traffic

r – Annual rate of growth of commercial traffic volume (in decimal)

n – Design period in years

$C = 365 \times 196((1+0.05)^{30}-1)/0.05$

C= 4753035

= Average number of axles (steering / single / tandem) per commercial vehicle 2.35

- Total two way axle load repetitions during the design period –

= 4753035 X 2.35

= 11169633

- No. of axles in predominant direction

= 11169633 X 0.5

= 5584816

- Design traffic after adjusting for lateral placement of axles (25 per cent of predominant direction traffic for multilane highways) –

  =5584816X 0.25

  = 1396204

- Night time (12 hour) design axles repetitions (Assumed 60% traffic at night time)

  = 1396204 X 0.6

  = 837722

- Day time (12 hour) design axles repetitions (100% - 60% = 40%)

  = 1396204 X 0.4

  =558482

- Day time six hour axle load repetitions

  = 558482 X 0.5

  = 279241

- Hence, design number of axle load repetitions for bottom-up cracking analysis

  = **279241**

- Night time six hour axle load repetitions

  = 837722 X 0.5

  = 418861

- % of commercial vehicles having the spacing between the front (steering) axle and the first axle of the rear axle unit less than 4.5m is 55%
- Hence, the six hour night time design axle load repetitions for top-down cracking analysis (wheel base < 4.5m)

  = 418861 X 0.55

  = **230373**

- The axle load category wise design axle load repetitions for bottom up and top down fatigue cracking analysis are given in the following Table

Table 49 Fatigue Crack Analysis

Axle Category	Proportion of the Axle Category	Category wise axle repetitions for Bottom-up cracking analysis	Category wise axle repetitions for Top-down cracking analysis
Front (Steering) single	0.45	103668	125658
Rear single	0.53	122098	147998
Tandem	0.02	4607	5585

BB. Cumulative Fatigue Damage (CFD) analysis for Bottom-Up Cracking (BUC) and Top-Down Cracking (TDC) and Selection of Slab Thickness

- Effective modulus of subgrade reaction of foundation, k – 231 MPa/m
- Elastic Modulus of concrete, E – 30000 MPa
- Poisson's ratio of concrete, μ - 0.15
- Unit weight of concrete, γ – 24 kN/m^3
- Design flexural strength of concrete – 4.95 MPa
- Max. day-time Temperature Differential in slab (for bottom-up cracking) – 17.0^{0}C
- Night-time Temperature Differential in slab (for top-down cracking) – day-time diff/2 + 5 = 13.50^{0}C
- Trial thickness of slab, h = 205 mm
- Radius of relative stiffness, $l = (Eh^3/(12k(1-\mu^2))^{0.25}$

  Where,

  l – radius of relative stiffness, m

  E – Elastic modulus of concrete, MPa

  h – concrete slab thickness, m

  k – modulus of subgrade reaction, MPa/m

  μ - Poisson's ratio of concrete

  = 0.55556

- 'Beta' factor in the stress equations will be 0.66 for doweled transverse joints for carrying out TDC analysis.

Computation of bottom-up and top-down cumulative fatigue damage is illustrated in following tables.

Table 50 Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	24420	2.784	0.562	87857	0.278	220 - 240	4146	2.267	0.458	18320259	0.000
105-115	12210	2.633	0.532	214376	0.057	200 - 220	461	2.131	0.431	infinite	0.000
95-105	24420	2.483	0.502	707338	0.035						
< 85	61049	2.181	0.441	infinite	0.000						
	188772	Fat Dam from Sing. Axles =			0.369		7123	Fat Dam from Tand Axles =			0.000

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential											
Rear Single Axle	**Rear Single Axles**					**Rear Tandem Axle**	**Rear Tandem Axles**				
Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Load Group (kN)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	29600	2.593	0.524	284225	0.104	220 - 240	5027	2.541	0.513	423020	0.011
105-115	14800	2.489	0.503	665309	0.022	200 - 220	559	2.437	0.492	1125609	0.001
95-105	29600	2.386	0.482	2107060	0.014						
< 85	73999	2.179	0.440	infinite	0.000						
	155737	Fat Dam from Sing. Axles =			0.140		5877	Fat Dam from Tand Axles =			0.012

It can be seen from the calculations given in the tables above that for the slab thickness of 205mmthe total fatigue damage for bottom-up cracking is 0.369 + 0.000 = 0.369. Total fatigue damage for top-down cracking is 0.140 + 0.012 = 0.152 and total cumulative fatigue damage (CFD) = 0.521 which is less than 1.0.

Hence, the trial thickness of 205mm is adequate.30mm thickness is added considering two retexturing in 30 years and 15mm for rounding off and hence a thickness of 250mm is appropriate.

Design of Dowel Bars

As per Table5 'Recommended Dimensions of Dowel Bars' of IRC: 58-2015,

- Diameter in mm - 32
- Length in mm – 450
- Spacing in mm - 300

Design of Tie Bars

Input Data:

- Slab Thickness – 0.205 m
- Lane width, b – 3.1 m
- Coefficient of friction, f – 1.5
- Density of concrete, kN/m^3 – 24
- Allowable tensile stress in deformed bars, MPa - 200(As per IRC:15-2017)
- Allowable bond stress for deformed tie bars, MPa – 2.46(As per IRC: 15-2017)

Design for Deformed Bars:

- Select diameter of tie bar, d_t – 12 mm
- Area of plain steel bar required per meter width of joint to resist the frictional force at slab bottom, A_s

$$A_s = bfW / S_{st}$$

Where,

A_s – area of steel in mm^2, required per m length of joint

b – Lane width in meters

f – Coefficient of friction between pavement and the sub-base/base (usually taken as 1.5)

W – Weight of slab in kN/m^2 and

S_{st} – allowable working stress of steel in MPa

=3.1X1.5X0.205X24000/200

=114.39 mm^2/m

- Cross Sectional Area of Tie Bar A = $\pi/4$ X $(12)^2$

  = 113 mm^2

- Perimeter of Tie Bar = πd = 37.7mm

- **Spacing of tie bars**, = A/A_s

  = 113/114.39X1000

  = 989 mm

  Say 950mm

- Provide spacing of 950mm c/c
- **Length of tie bar**

  $L = 2S_{st}A_{cs} / BXP_{ptb}$

  Where,

  L –Length of tie bar, mm

  S_{st} – allowable working stress in steel, MPa

  A_{cs} – cross sectional area of one tie bar, mm^2

  P_{ptb} – perimeter of the tie bar, mm and

  B – Permissible bond stress of concrete, 2.46 MPa

  = 2 X 200 X 113 / (2.46 X 37.7)

  = 487.80 mm

- Increase length by 100mm for loss of bond due to painting and another 50mm for tolerance in placement
- Therefore the required length of tie bar is 640mm

Table 51 Pavement Composition:

Sr. No.	Description	Thickness in mm
1	Pavement Quality Concrete (PQC)	250
2	Dry Lean Concrete (DLC)	100
3	Granular Sub-Base (GSB) (as Drainage Layer)	150
4	Selected Subgrade (CBR ≥ 8%)	500

2.6 INFRASTRUCTURE AND UTILITIES PLANNING

2.6.1 Planned Utilities

Dedicated and planned utilities are one of the key features of smart roads. Various utilities planned under DPR-5 Smart Road include wet utilities include Water Supply, sewerage and storm water drainage system as well as dry utilities like Street Lights, Power Distribution and OFC.

Water Supply Distribution lines are proposed under ADB funding as a separate Project and funding. Necessary coordination with the Consultants working on ADB project and MCC has been carried out to ensure integration of proposals in a holistic manner.

Similarly; UGD (Underground sewerage network) and LED Street lighting are proposed as separate Project under Mangaluru Smart City. The proposal under UGD and LED project have been integrated while planning the utility corridor along DPR-5 Smart Road.

2.6.2 Electrical Infrastructure

The detailed survey of existing electrical utilities has been carried out along with MESCOM officials and same is included in drawings along with the report. The space planning for electrical services in the proposed utility corridor is based on the assessment and requirement of MESCOM Following details are as per assessment.

Table 52 Existing Transformer locations

Road no	Name of Road	Road		Road Length in Mtr	Transformer number	Location of transformer	Transformer pole number/MESCOM Identification number
		From	To				
7a	**Milagres Cross Rd.**	KMC Central Library Jn.	Milagres Church Jn	183	0		
7c	**Nandigudda Rd.**	Attavar Rd.	Mglr.Railway Rd.	1021	TR-1	Rotary Physiotherapy Center	-
					TR-2	Hotel Residency Park	20030261245 DTC
					TR-3	IMA House Bldg.	20030261268
8	**New Balmatta Rd.**	Jyoti circle	Ivory Juction	577	TR-1	G+ 12 Bldg.	20030315408 DTC 20030315407
					TR-2	Smart Tower Bldg.	-
					TR-3	G+4 Bldg.	20030315399 DTC
					TR-4	G+4 Ramanik Bldg.	200315370
					TR-5	G+6 Crescent Manor Bldg.	20030315366
					TR-6	Near Shops	20030315357 DTC
10	**Don Bosco hall cross Rd.**	KMC Mercara Trunk Rd.	Ivory Juction	375	TR-1	Behind GI Bakery Bldg.	2003015352 DTC
					TR-2	Opp : Falnir Lab	20030263299 DTC 20030263298
					TR-3	Opp : Falnir Lab	20030263296
					TR-4	Ashok Palace Bldg.	20030263513
					TR-5	Land Trades Bldg.	200326381 DTC
19	**Arya Samaj Rd.**	Balmatta Circle	Mangalore Hospital	925	TR-1A	G+3 Bldg. Maco Co-Op.	
					TR-1	Presidency Avenue Bldg.	20030262548 DTC 20030262549
					TR-2	Opp: PRESIDENCY AVENUE BLDG.	
					TR-3		20030262545 DTC 20030262544
					TR-4	Mothisham Oasis	20030262541

						Bldg.	
					TR-5	Tranqil Heights Bldg.	20030262535 DTC
					TR-6	Classic legacy Bldg.	20030262528 DTC 20030262529
					TR-7	Mothisham Galaxy Bldg.	20030262871
					TR-8	Happy Home Apmts.	
					TR-9	Inland ExcllencyApmts.	20030262520 DTC
					TR-10	Parvathi Bldg.	20030262516 DTC
					TR-11	Geern View Bldg.	20030262554 DTC
					TR-12	Green Orcade Bldg.	
15a	**Jumma Masjid Rd.**	Car Street	Bunder Police Station	717	**TR-1**		**20030205586DTC**
					TR-2	**MARIAM PLAZA APTS**	**I.D.12180**
					TR-3		**20030258209DTC**
					TR-4	**HIBA TOWER APTS**	**M.I.D 12153**
					TR-5	**CORPORATION CLINIC**	**M.I.D 12098**
					TR-6		**20030230800DTC**
					TR-7	**VINAYAKA**	**M.I.D 12040**
					TR-8	**BUNDER POLICE STN**	**M.I.D 12005**
15b	**Port Rd.**	Bunder Rd.	Badria School Jn.	966	0		
20	**Bengre Ferry Rd.**	Jumma Masjid	BMS Ferry Lane	1103	**TR-1**	MM Tower	12307
					TR-2	North Warf	12304
					TR-3	Port Office	12219
					TR-4	Dariya ICE Plant	12055

Base on existing survey and discussion with MESCOM, space requirement for Electrical cables were finalized as per below mentioned table which is also included space for spare pipe for HT cable as per MESCOM recommendation and the same is accommodated in Road sections.

Table 53 Existing Electric Cable/Pipes locations

Rd. no.	Name of Rd.	Road		No of pipe require (Left Side)		No of pipe require (Right side)	
		From	To	415V	11kV	415V	11kV
7a	**Milagres Cross Rd.**	KMC Central Library Jn.	Milagres Church Jn	1		1	2
7c	**Nandigudda Rd.**	Attavar Rd.	Mglr.Railway Rd.	2		2	4
8	**New Balmatta Rd.**	Jyoti circle	Ivory Juction	2	4		
10	**Don Bosco hall cross Rd.**	KMC Mercara Trunk Rd.	Ivory Juction	4	4	2	4
15a	**Jumma Masjid Rd.**	Car Street	Bunder Police Station	2	2	2	2
15b	**Port Rd.**	Bunder Rd.	Badria School Jn.	1		1	2
19	**Arya Samaj Rd.**	Balmatta Circle	Mangalore Hospital		2	2	4
20	**Bengre Ferry Rd.**	Jumma Masjid	BMS Ferry Lane	2	2	2	2

2.6.3 Street Light

Location of lighting poles are considering base on following requirement to achieve desire lux level.

1. Total ROW
2. Type or category of roads
   a. Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways
   b. Secondary roads with considerable traffic like local traffic routes, shopping streets
   c. Secondary roads with light traffic
3. Visibility of Roads and surroundings.
4. Visual guidance of the shape of the road. Motorist should be able to identify bends and curves and change in roads
5. The visual comfort of the driver/pedestrian.
6. Uniformity of lighting

Lighting design is considered based on standard lux level as per the BIS standards & BEE guidelines as per below mention table

Table 54 Classification of lighting installation

Classification of lighting installation	Type of Road	Average level of illumination on road surface
Group A1	Important traffic roads carrying traffic/	30
Group A2	Other main road carrying mixed traffic likes main city stations, arterial road, throughways etc	15
Group B1	Secondary road with considerable traffic like principle local traffic routes, shopping street etc.	8
Group B2	Secondary road with light traffic	4

All roads in this package is falls under Group A2 classification so while placing of light fixtures minimum Average lux level considered 15 Lux.

2.6.4 Lighting Poles:

In existing scenario, majorly light fixtures are installed on Electrical poles and some of the light fixtures are installed on 7 meter high poles. Existing 7 meter poles area retain and only location will be shifted as per Road plan and width and in addition to existing poles new poles are used base on requirement. Locations of poles are marked in drawing.

2.6.5 Centralized street lighting control

"Conversion of Conventional Street Lights into LED with

Smart Lighting Solutions" is one of the projects under MSC with an objective of reducing energy consumption as well as to reduce impact on environment by conventional lamps. The existing street lights are proposed to be converted into LED on PPP basis under a separate project. Smart LED street lighting system adopts centralized control system which will result in further saving of electrical energy. This system offers following Merits –

1. Central control, fault detection
2. Generation of burn hours reports
3. Automatic operation with astronomical timers
4. Manual operation from a central location through GPRS / GSM system
5. Remote metering
6. Voltage stabilization

Energy consumed by the LED lighting is much less as compared to the sodium vapour lighting. This will reduce the energy bill of street lights to great extent.

SMART STREET LIGHTING SOLUTIONS PROPOSED UNDER SMART ROADS WILL BE TAKEN UP UNDER SEPARATE TENDER FOR LED STREET LIGHTS PPP PROJECT COMPONENTS.

2.6.6 Wet Utilities

The wet utilities include Water Supply, sewerage and storm water drainage system.

Majority of the underground drainage system in the ABD area had been executed under the 1961 scheme by Public Health Department. The underground drainage system is exhausted/lived its design life and a necessity has arisen to replace the existing lines with the new pipelines. Considering the above conditions, the Government of Karnataka has decided to take up underground drainage system for the ABD area of Mangalore under Smart city.

In order to achieve this objective, GoI / GoK in its Smart city program, has approved a underground drainage project to Mangaluru Municipal Corporation for an estimated cost of 37.5 crores to meet the intended objective.

The aim of the UGD DPR is to perform a detailed analysis and design of UGD network. The detailed Sewerage network design has been carried out for ABD area. The proposed sewerage system consist lateral and branch networks from Sewerage Zones draining into respective wetwells.

The sewerage system is designed using ***Bentley Sewer Gems V8i*** version software.

The sewage from the individual properties will be collected and conveyed to the wet well by gravity sewers. In the proposed system, laterals are proposed along the roads to connect sewage from Individual property chambers and it is connected to branch sewers. Branch sewers are joined to main sewers and which is connected to existing Trunk sewer which is connected to the Wetwell. The Sewage from the Wetwells in ABD Area are pumped to the 43.5MLD Sewage Treatment Plant at Kavoor. Proposed sewers are of UPVC pipes.

Considering the economics of the repair of concrete roads, the sewerage network is not planned for concrete roads. So the existing sewerage network is retained in Roads 7a, 7c, 10, 15a, 15b and 20. New Sewer network is proposed along the roads 8, 10 , 19. 200mm diameter upvc pipe is provided for laterals and circular RCC manholes with SFRC cover and frame ranging from 1.2m to 1.5m in diameter has been provided in the proposed scheme

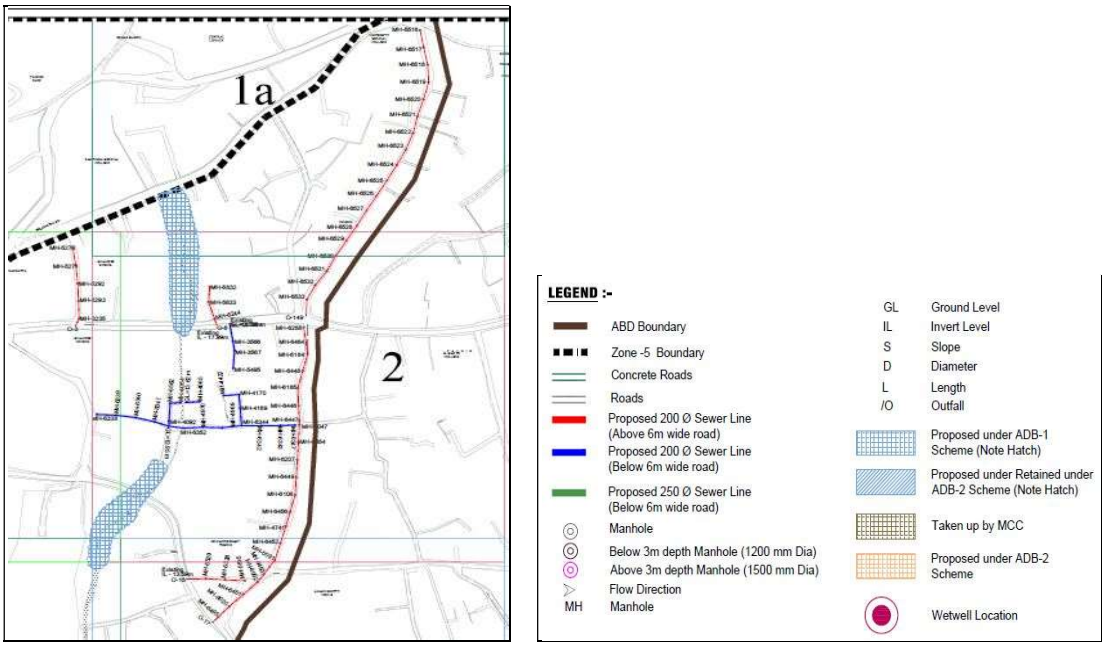

Figure 33 Mark-up showing the UGD lines proposed in Roads along Road 8

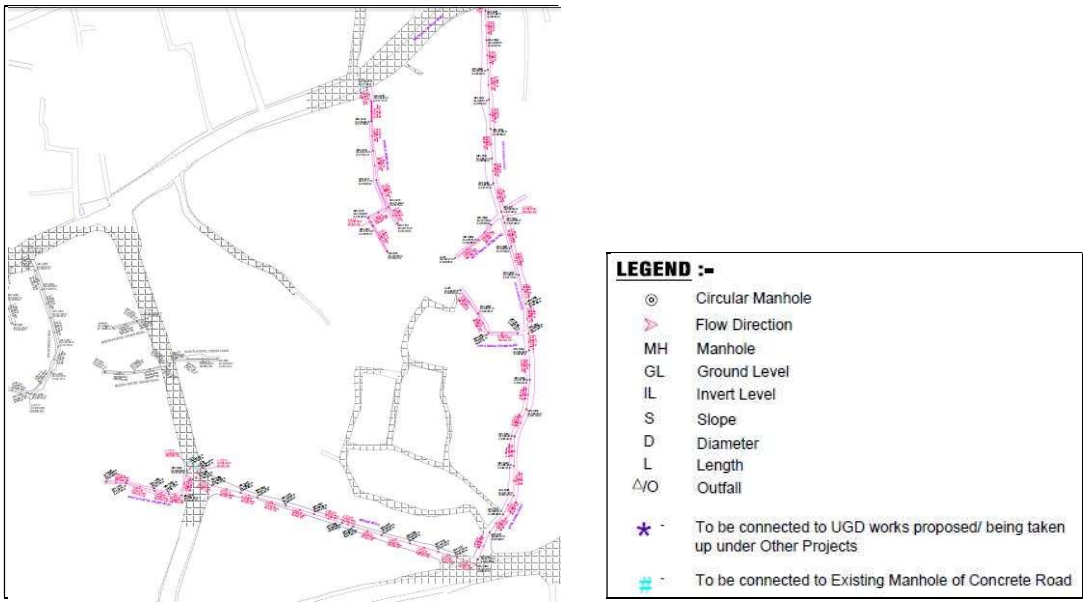

Figure 34 Mark-up showing the UGD lines proposed in Roads along Road 19

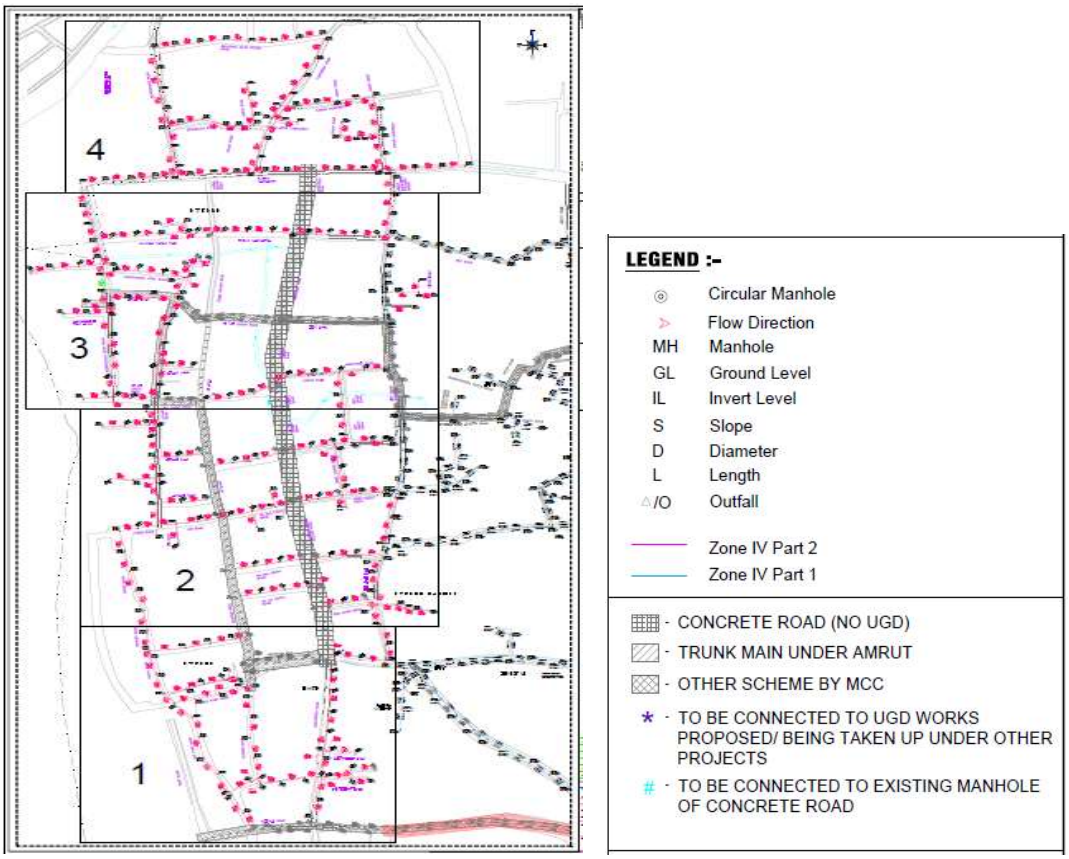

Figure 35 Mark-up showing the UGD lines proposed in Roads 15a, 15b & 20

Mangaluru city has a well planned water distribution network. Several augmentation works have been proposed under various infrastructure development schemes to improve the transmission and distribution of water supply in the city. The details of the same have been incorporated during the planning of smart roads so that all the utilities shall be implemented in co-ordination.

Storm water drains are provided along the road side to collect the runoff during rainfall. The drains are designed for a rainfall intensity of 80mm/hr as obtained from the IDF-curve using Manning's equation for flow through open channels. Rectangular RCC drains 600mm to 1200mm in width has been proposed to collect storm water by gravity. The existing storm water drains in good condition and newly constructed drains shall be retained. The existing drains shall be desilted and refurbished to enhance the carrying capacity of the drain. The following figure shows the output of the design for storm water drainage.

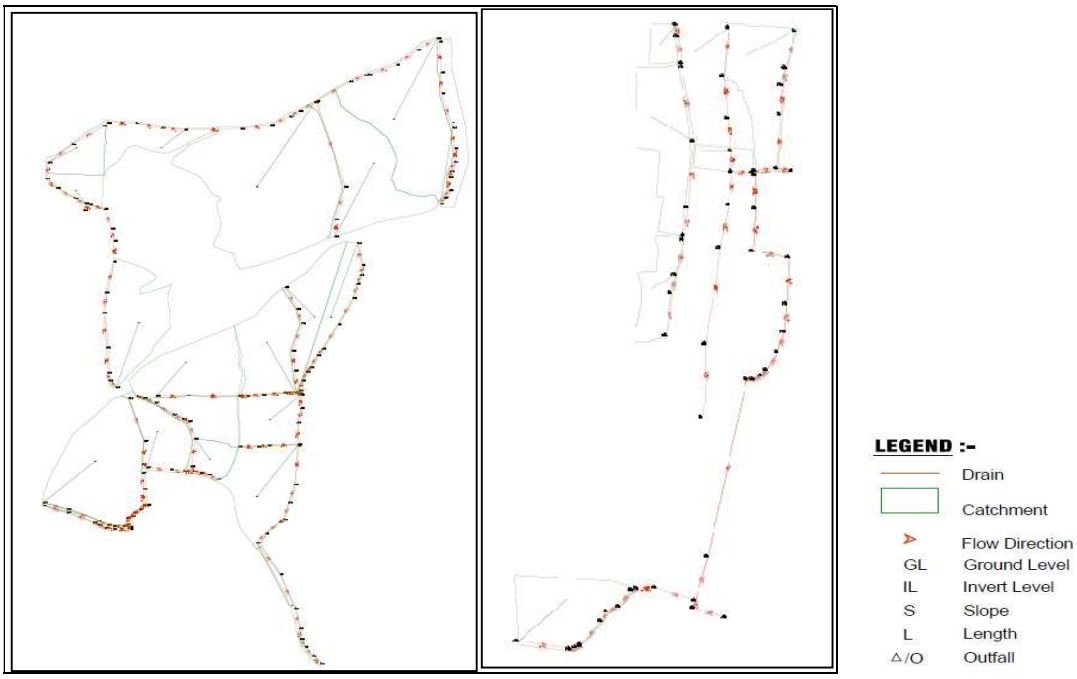

Figure 36 Storm water drainage on the considered roads

The details of storm water drainage network along these roads are provided in the proposed cross-sections of the road prepared in co-ordination with all the other utilities.

Figure 37 Existing drain and newly constructed drain along 7a

Figure 38 Existing drains along 7c

Figure 39 Drains in New Balmatta Road-8

Figure 40New drains being constructed along Road-10

Figure 41 Existing drains along 15a

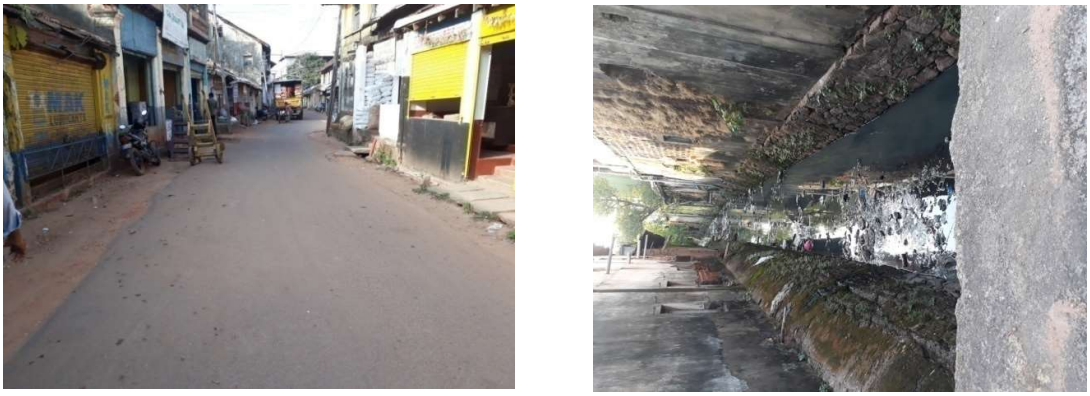

Figure 42 Existing drains along 15b

Figure 43 Existing drains along 19

Figure 44 Existing drain along Road 20 & No drain along Port area

Table 2.6-55 Details of Utilities along DPR-5 Roads

S.NO	Road ID	Sewer				Water Supply			SWD		
		Length(m)	Diameter (mm)	Manhole Size(m)	Qty(Nos)	Dia(mm)	Qty(Nos)	Sluice Valve Qty (Nos)	Width(mm)	Orientation	Retain
1	7a	123.6	200	1.2	4	90	1	1	600		Retain
2	7c	Existing Network to be retained				300	1	1			Retain
						63	2				
						160	1	1			
						110	1				
3	8	497.1	200	1.2	13	110	1		600	one side	
				1.5	6						
4	10	Existing Network to be retained				110	1			one side	Retain
						63	1				
5	15a	Existing Network to be retained				110	1	5	600	both sides	
						63	1				
6	15b	**Trunk Main for Zone -4 under AMRUT Scheme** (Bombay Lucky Hotel to MG Cross Road) Existing Network to be retained on Concrete Part				160	1		600	both sides	
						110	1	3			
						63	1				
7	19a	Existing Network to be retained				250	1		600	one side	
						160	1				
						110	1				
		543.1	200	1.2	22	63	2				
8	20	227.1	200	1.2	10	110	1	3	600	one side	
						90	1				
						63	2				

Majority of the Sewer lines in the present DPR has been taken up under UGD Package -4 which includes Zone-5 & Zone-6 in ABD area. The Overall Summary of UGD Package -4 is mentioned in the following table

Table 56 Overall Summary of UGD Package-4

PACKAGE	ZONE	LENGTH **(KM)**	COST (CRORES)	WETWELL LOCATION	HOUSE SERVICE CONNECTIONS(Nos)
DPR-5	Zone-5(Road Width >6m)	7.01	8	Pandeshwar-WW-5	748
	Zone-5(Road Width <6m)	10.67	11.5		
	Zone-6	5.29	5.7	Mulihitlu-WW-6	
	Total	**22.9**	**24.5**		

The total cost of UGD Package -4 is 24.50 Crores. The cost abstract of this package is mentioned in following table

Table 57 Cost Abstract-UGD Package-4

Sr.No.	Description	Estimate cost in Rs.
A	**Underground Drainage**	
i	Zone 5 (Road width >6m)	5,66,39,402.00
ii	Zone 5 (Road width <6m)	8,32,19,273.00
iii	Zone 6 (Road width <6m)	3,62,86,901.00
B	**Utility Shifting – Compound Wall, Culvert and RCC Drain**	
i	Zone 5 (Road width >6m)	16,21,728.00
ii	Zone 5 (Road width <6m)	23,80,523.00
iii	Zone 6 (Road width <6m)	10,81,089.00
C	**Electrical Pole Shifting**	
i	Zone 5 (Road width >6m)	19,94,179.00
ii	Zone 5 (Road width <6m)	33,26,214.00
iii	Zone 6 (Road width <6m)	12,87,912.00
	Total Rs.	**18,78,37,220.00**
	Escalation	1,87,83,722.00
	Contingency at 3%	56,35,117.00
	Tax as applicable ,	2,25,40,466.00
	Administrative charges, Miscellaneous and rounding off (LS)	1,02,03,475.00
	Grand Total Rs.	**24,50,00,000.00**

The following table provides the cost of different components and their percentage contribution to the total cost of the UGD Package-4 DPR.

Table 58 Components of UGD Package-4 DPR

DESCRIPTION	COST IN INR	% CONTRIBUTION
Excavation	1,60,29,900.00	10%
Pipe	1,66,63,764.00	10%
Manholes	4,70,14,640.00	30%
House Service Connections	55,56,233.00	4%
Inspection Chambers	86,95,792.00	5%
Road Restoration	5,30,51,706.00	33%
Utility Shifting	1,16,91,645.00	7%

The roads 15a, 15b, 19 & 20 are a part of Zone-4 & Zone-3. The concrete portions along these roads are not considered for this package. This Package has been technically sanctioned by KUIDFC and Work order has been issued. Construction is yet to be started along these roads. The total cost of the package is 9.5 crores. This package includes a part of Zone-4 and a part of Zone-3. The overall Summary of Package 02 is provided in the Table below.

Table 59 Cost Abstract-UGD Package-2

PACKAGE	ZONE	LENGTH (KM)	COST (CRORES)	WETWELL LOCATION	HOUSE SERVICE CONNECTIONS(Nos)	STATUS
DPR-2	Zone-4(Part) & Zone-3(Part)	8.04 (6.37 & 1.67)	9.5	Kandathpalli-WW-4 & Kudroli –WW-3	1260	Work order issued

The cost abstract of this package is provided in the Table below.

Table 60 Cost Abstract-UGD Package-2

Sr.No.	Description	Estimate cost in Rs.
I	Underground Drainage	68,619,965.00
II	Utility Shifting – Compound Wall, Culvert and RCC Drain	1,811,827.00
III	Electrical Pole Shifting	2,242,472.00
	Total Rs.	**72,674,264.00**
	Escalation	72,67,426.00
	Contingency at 3%	2,180,228.00
	Tax as applicable ,	8,720,912.00
	Administrative charges, Miscellaneous and rounding off (LS)	4,157,170.00
	Grand Total Rs.	**95,000,000.00**

Table 61 Components of UGD Package-2 DPR

DESCRIPTION	COST IN INR	% CONTRIBUTION
Excavation	23,27,238.00	10%
Pipe	19,32,973	8%
Manholes	70,71,534	30%
House Service Connections	7,71,019	3%
Inspection Chambers	16,06,154	7%
Road Restoration	75,33,870	32%
Utility Shifting	20,70,106	9%

Thus the utilities shall be planned and coordinated in conjunction with the design and construction of smart roads.

2.7 STUDY FINDINGS AND OBSERVATIONS

2.7.1 Future Strategies as per Traffic Analysis

1. Milagres Cross Road and Jumma Masjid road can operate with their existing lane configuration without any capacity augmentation during the horizon period. Rest of the roads are getting saturated and need capacity augmentation. However, this being a developed town space is a constraint.
2. However, this being already developed town, expansion of the width of the roads is not possible due to development on both ends right now. Based on Master Plan proposals, Mangalore City Corporation has approved certain road widths. As and when the road widening is taken up, capacity augmentation of these roads can be taken up.
3. Moreover, the Design Service Volumes refer to Level of Service (LoS) C, which is, generally, at 0.7 of the Capacity. Further, traffic volume greater than capacity is often observed in Urban areas with lower Level of Service.
4. Considering the above, it is suggested to deploy traffic management strategies, coupled with promotion of the Public Transport System to reduce the number of vehicles on the road.
5. However as per IRC 41, grade separation is warranted if the traffic on major road crosses more than 45,000 vehicles and minor road traffic crosses more than 12,000 vehicles per day. Milagres Cross Road, Avery junction and Arya Samaj Road Junction get qualified for grade separation. However, space is a constraint. Considering this grade separation is recommended as and when space is available at these locations and for the time being improvement of the junctions is suggested.

6. Mid block and at junction control measures are proposed for the pedestrians as the PV2 values are higher than 2x108 at many locations.

2.7.2 Summary of Findings

1. Mangalore Smart City Limited (MSCL) is implementing the Smart City Proposals with the help of the Project Management Consultants. Development of Smart Roads is one of important projects in the Smart City Proposal. Safe pedestrian movement along with smart features is key in the development of the Smart Roads.
2. This report deals with the DPR 5 for the Smart roads. Eight roads are considered under DPR 5 and are: Milagres Cross Road, Nandigudda Road, New Balmatta Road, Don-Bosco Hall Road, Arya Samaj Road, Jumma Masjid Road, Port Road and Bengre Ferry Road.
3. Traffic surveys are conducted on these roads to get the base year mode wise traffic statistics. These are analyzed and the peak hour traffic volumes both in terms of number of vehicles and PCU are worked out. Projections for future are made applying appropriate growth rates.
4. Capacity Analysis shows Milagres Cross Road and Jumma Masjid road can operate with their existing lane configuration without any capacity augmentation during the horizon period. Rest of the roads are getting saturated and need capacity augmentation. However, this being a developed town space is a constraint.
5. Based on Master Plan proposals, Mangalore City Corporation has approved certain road widths. As and when the road widening is taken up, capacity augmentation of these roads can be taken up.
6. Moreover, the Design Service Volumes refer to Level of Service (LOS) C, which is, generally, at 0.7 of the Capacity. Further, traffic volume greater than capacity is often observed in Urban areas with lower Level of Service.
7. Considering the above, it is suggested to deploy traffic management strategies, coupled with promotion of the Public Transport System to reduce the number of vehicles on the road.
8. Grade separation is warranted at Milagres Cross road junction, Avery Junction and Arya Samaj Road Junctions. Once again space constraints are there. In view of this, signalization of these junctions is proposed as and when the capacity of uncontrolled junctions are reached.
9. Mid block and at junction control measures are proposed for the pedestrians as the PV2 values are higher then 2x108 at most of the locations.

2.7.3 Trial Pit Reports

सिविल अभियान्त्रिक विभाग
राष्ट्रीय प्रौध्योगिकी संस्थान कर्नाटक, सुरत्कल
पोस्ट श्रीनिवासनगर, मंगलूरु - 575 025

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY KARNATAKA, SURATHKAL

POST SRINIVASNAGAR, MANGALURU - 575 025

Date : 10.01.2019

SOIL TEST REPORT

This report is in response to the request made by Dr. Nitin Bhavsar, Team Leader, Wadia techno-Engineering Services Ltd., Bangalore. Vide his letter No. WTESL/2292/MSCL/267 dated 04th December 2018. It is requested to conduct laboratory modified Proctor compaction tests and California Bearing Ratio (CBR) tests on supplied soil samples. 36 soil samples were supplied. All these soil samples belong to road project of Mangalore Smart City Project in ABD area of Mangalore. This is the first report (of tests completed so far), and subsequent reports will follow as and when the other tests are done.

Following are the results

Rd. No.	Sample No. & type of soil	Name of Road	Road		Modified compaction test results		Soaked CBR values of soils at max. dry density (%)
			From	To	Max. dry density (kN/m³)	OMC (%)	
1c	1 Silty sand	Pandesh-wara New Rd.	Rosario Church Rd.	Pande-shwar New Rd.	20.7	7.0	10.0
1c	2 Silty sand				20.7	9.3	8.0
2	1 Gravelly silty sand	Old Kent Rd.	Old Kent Rd.	Kerai Samaja Rd.	19.2	11.0	8.0
2	2 Gravelly silty sand				19.4	9.8	7.0
20	1 Silty sand	Bendre Ferry Rd.	Jumma Masjid	BMS Ferry Lane	20.4	9.5	10.0
20	2 Silty sand				20.6	9.7	10.0

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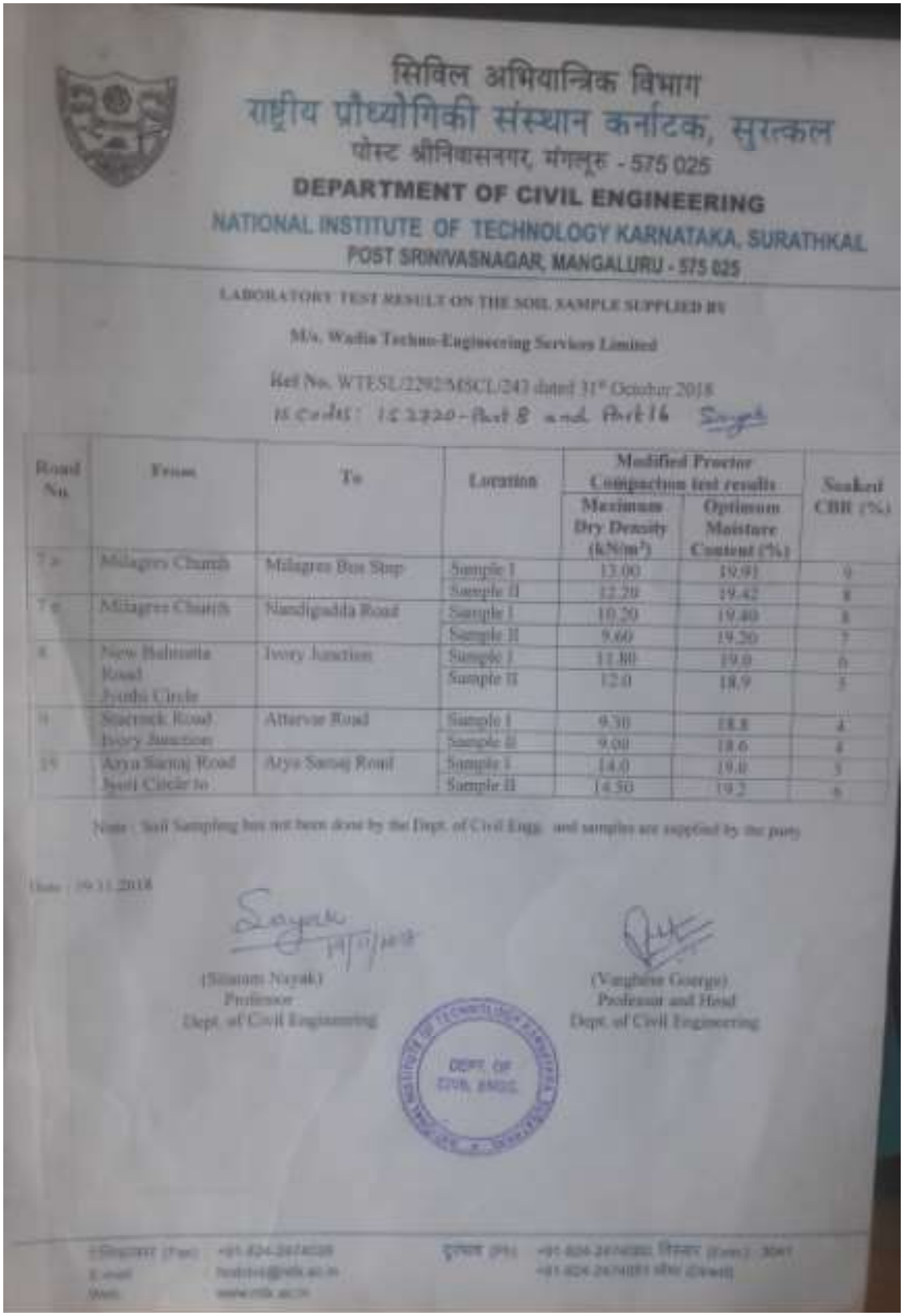

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LABORATORY TEST RESULT ON THE SOIL SAMPLE SUPPLIED BY

M/s. Wadia Techno-Engineering Services Limited

Ref No. WTESL/2292/MSCL/243 dated 31st October 2018

IS Code: IS 2720-Part 8 and Part 16

Road No.	From	To	Location	Modified Proctor Compaction test results		Soaked CBR (%)
				Maximum Dry Density (kN/m³)	Optimum Moisture Content (%)	
7 a	Milagres Church	Milagres Bus Stop	Sample I	13.00	19.91	9
			Sample II	12.20	19.42	8
7 c	Milagres Church	Nandigudda Road	Sample I	10.20	19.40	8
			Sample II	9.60	19.20	7
8	New Balmatta Road Jyothi Circle	Ivory Junction	Sample I	11.80	19.0	6
			Sample II	12.0	18.9	5
9	Shattuck Road Ivory Junction	Attavar Road	Sample I	9.30	18.8	4
			Sample II	9.00	18.6	4
15	Arya Samaj Road Jyoti Circle to	Arya Samaj Road	Sample I	14.0	19.0	5
			Sample II	14.50	19.2	6

Note : Soil Sampling has not been done by the Dept. of Civil Engg. and samples are supplied by the party

Date : 19.11.2018

(Sitaram Nayak)
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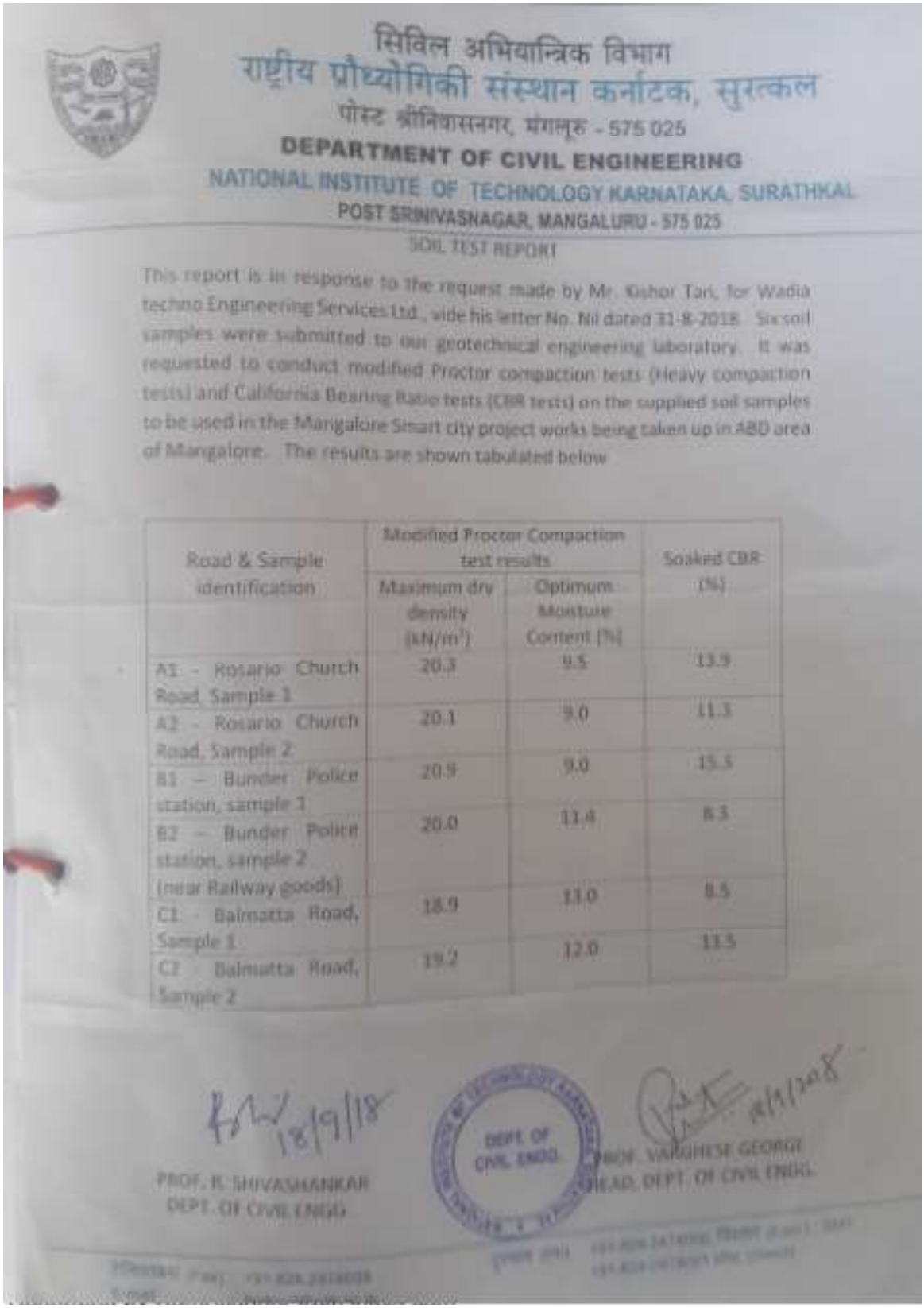

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SOIL TEST REPORT

This report is in response to the request made by Mr. Kishor Tari, for Wadia techno Engineering Services Ltd., vide his letter No. Nil dated 31-8-2018. Six soil samples were submitted to our geotechnical engineering laboratory. It was requested to conduct modified Proctor compaction tests (Heavy compaction tests) and California Bearing Ratio tests (CBR tests) on the supplied soil samples to be used in the Mangalore Smart city project works being taken up in ABD area of Mangalore. The results are shown tabulated below

Road & Sample identification	Modified Proctor Compaction test results		Soaked CBR (%)
	Maximum dry density (kN/m³)	Optimum Moisture Content (%)	
A1 - Rosario Church Road, Sample 1	20.3	9.5	13.9
A2 - Rosario Church Road, Sample 2	20.1	9.0	11.3
B1 – Bunder Police station, sample 1	20.9	9.0	15.3
B2 – Bunder Police station, sample 2 (near Railway goods)	20.0	11.4	8.3
C1 - Balmatta Road, Sample 1	18.9	13.0	8.5
C2 - Balmatta Road, Sample 2	19.2	12.0	13.5

18/9/18

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Chapter 3 PROPOSED DESIGN COMPONENTS

3.1 Smart Road Components – Urban Design, Landscape and ITMS

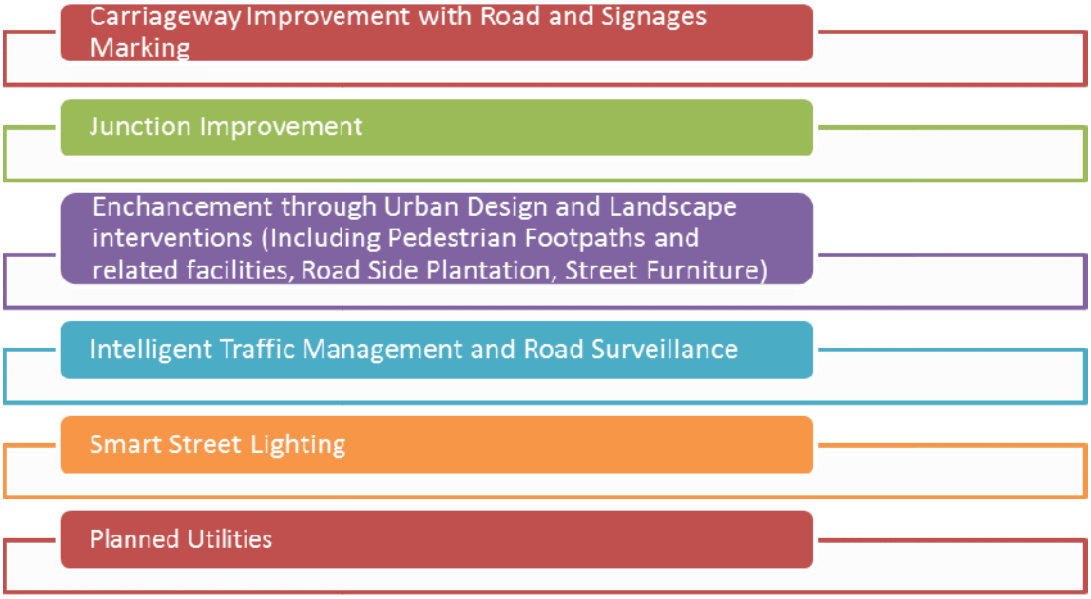
3.1.1 Urban Design and Landscape

Transforming existing roads into Smart Roads has been envisaged under the Smart City Mission. The design of Smart roads intends to develop world class road infrastructure inclusive to all strata of society with consideration for pedestrian safety and security as a prime importance. This entails comprehensive upgrading of the public Right of Way (ROW) of the streets which includes refurbishment of existing carriageway, laying of new footpaths and cycle tracks, creating utility corridors, developing pedestrian facilities, development works for landscape, hardscape, street furniture, signage, lighting, etc.

The proposed intervention aims to achieve the following:

- Seamless mobility for citizens of Mangaluru
- To eliminate traffic congestion and facilitate smooth flow of traffic
- To create inclusive road infrastructure for all strata of society
- Promote environmentally sustainable means of transport

The Smart Road proposal would consist of the following specific interventions:



Proposals for Carriageway Improvement, Roads and Signage's, Junction Improvement have been covered under Chapter 4 and 5 of the Report. The Subsequent Sections provide details of other proposed smart elements, mentioned above, including Junctions.

Design of Smart roads in Mangaluru is with compliance to following guidelines:

1. Indian Road Congress code
2. MoUD – Indian Urban Transport Guidelines.

3.1.2 Proposed Design Considerations

The main parameters considered here are as follows:

1. Continuous footpath
2. Tactile paving present on the roads where footpath more than 1.5m is available.
3. LED street lights

Due to constraints of the adjacent buildings and narrow ROW, landscape spaces and street furniture are not considered in these roads. The following table shows the summary of the pedestrian facilities and smart elements considered in DPR-5.

3.1.3 Urban Design Features

Salient Features of Smart Roads for DPR-5 ROADS:

Road Cross Section:

Carriage way: As per MoUD code for Urban roads, the lane widths proposed in the DPR roads varies between 3.0-3.5. In most of the roads Concrete roads are developed recently about 3-5 years back. Since further road widening is not possible at this point of time, it is proposed to retain the existing roads judiciously and add necessary width of for the footpaths for the safe movement of pedestrians.

Parking Lane: The parking lane of 2.5m is proposed. Wherever space constraints were observed, parking lane was planned by adopting the Parking Norms as per the Mangalore Zonal Regulations (1.25 m). Permeable grass pavers are proposed at the parking lane so that it helps to percolate the rain water and increase the ground water table.

a. **Median:** Medium height shrubs are proposed at the median where ever adequate width of the median is available. However, no shrubs are proposed near median opening to provide for necessary line of sight.

Pedestrian Facilities and Smart Elements:

a. **Footpath:** Wide footpath of minimum width 1.5m to maximum 4m are proposed taking into consideration the pedestrian count on the selected roads.

b. **Barrier free design:** Tactile paving is proposed at the centre of the footpath on all the DPR-5 Smart Roads. Curb ramps are present at the property entrances and parking bays for wheel chair access. Audio visual signals for blind people at the junctions.

c. **Bollards:**Bollards are proposed at the property entrances and parking bays in order to avoid two wheeler movements on the footpath.



d. **Footpath lighting**: Pole lights are proposed at a distance of 10m c/c for illumination of footpath for pedestrian safety and security. The pole lights are incorporated with the advertisement panels which is one of the means for revenue generation.

e. **Street furniture**: Street Furniture includes some interactive seating spaces, benches along the footpath. Dustbins, SIGNAGE like parking sign, stop sign, pedestrian crossing, bus stop are proposed at proper locations.

f. **Table top crossing**: Table top crossing is proposed at junctions so as to have a smooth pedestrian movement and subsequently resulting into reduction of speed of the vehicles at the junction.

g. **Other smart features** included are LED street lights to illuminate the carriage way, smart poles at the junction and audio-visual signals at the pedestrian crossings for differently-abled people.

Figure 45 Typical Proposed Model of Pedestrian Crossing and Smart Elements

Following are the list of drawings prepared for Urban Design elements of DPR-5 Smart Roads

Table 62 List of Cross Sections

No.	Drawing no	Drawing Title	No of Sheets
1	WTE_2292_04_R_5.01	PROPOSED CROSS SECTION OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	**3**
2	WTE_2292_04_R_5.02	PROPOSED CROSS SECTION OF ATTAVARA NANDIGUDA ROAD (ROAD NO. 7c)	**20**
3	WTE_2292_04_R_5.03	PROPOSED CROSS SECTION OF NEW BALMATTA ROAD (ROAD NO. 8)	**11**
4	WTE_2292_04_R_5.04	PROPOSED CROSS SECTION OF KUDUMBI GARDEN (DBS) ROAD (ROAD NO. 10)	**8**
5	WTE_2292_04_R_5.05	PROPOSED CROSS SECTION OF ARYA SAMAJ ROAD (ROAD NO. 19a)	**12**
6	WTE_2292_04_R_5.06	PROPOSED CROSS SECTION OF BALMATTA ROAD (ROAD NO. 19b)	**6**
7	WTE_2292_04_R_5.07	PROPOSED CROSS SECTION OF AZIZUDDIN ROAD (ROAD NO.15a)	**15**
8	WTE_2292_04_R_5.08	PROPOSED CROSS SECTION OF JUMMA MASJID-OLD PORT ROAD (ROAD NO.15b)	**21**
9	WTE_2292_04_R_5.09	PROPOSED CROSS SECTION OF BENGRE FERRY ROAD (ROAD NO.20)	**23**

Table 63 Proposed Pedestrian Facilities

Road no	Road Name	Smart Features					Pedestrian Facilities					
		MUBs (trench)	Bus Shelter with E-Toilet	LED lights	Street furniture like signage, dustbins, benches, advt boards	Audi-visual signals	Road side plantation with tree grates	Pedestrian Crossing	Tactile paving and wheel chair access	Spaces for informal commercials	Subways or FOBs	Parking for Auto rickshaws
7a	Milagres Cross Rd.	√	x	√	√	x	x	√	√	x	x	x
7c	Attavara-Nandigudda Rd.	√	x	√	√	x	x	√	√	x	x	x
8	New Balmatta Rd.	√	x	√	√	x	x	√	√	x	x	x
10	Kudumbi Garden (DBS) Road	√	x	√	√	x	√	√	√	x	x	x
15a	Azizuddin Road	√	x	√	√	x	x	x	√	x	x	x
15b	Jumma Masjid-Old Port Rd.	√	x	√	√	x	x	x	√	x	x	x
19a	Arya Samaj Rd.	√	x	√	√	x	x	x	√	x	x	x
19b	Balmatta Road	√	√	√	√	x	√	√	√	x	x	x
20	Bengre Ferry Rd.	√	x	√	√	x	x	x	√	x	x	x

3.1.4 Landscaping

Roads like the any other transportation hub gives an identity to the place. It plays a vital role in visual experience of user. Mangaluru city has a composition of terrain from plains towards the coastal region to undulating topography toward the Western Ghats on the east. Owing to which the road also has varying gradient and character.

The Road side landscape would enhance the experience of the commuter in terms of microclimate and aesthetics along with ensuring safety. Further it would enrich the experience of the commuters with the natural seasonal dynamism of the plant species

Roads in Central node are one of the prominent roads in the city and encircle the eminent open space along the Town hall. This road also has some of the very old and huge rain trees which give it an identity.

Landscape design has been deliberated with understanding the complex nature of the site, the dynamic relationship between the natural and built environment and overlaying cultural context.

Landscape intervention has been proposed considering the above principle; consequently, have carved out green spaces between the carriage way and footpath to refrain and restrict pedestrian crossing at random locations. This would ensure systematic and swift pedestrian and vehicular circulation.

The median has been designed with a thick green hedge with appropriate height to ensure sight of vehicle in the adjacent lane and cut the glare. This would also restrict pedestrian movement to cross at vulnerable spots.

Further, following aspects should be considered while proposing landscape design

- Use landscape and aesthetics tools to reduce the visual complexity at intersections
- Focus on the use of visual contrasts in material textures and colours to make the functional components of the highway intersection visually prominent.
- Accessibility for maintenance must also be considered
- Select plant materials that will not obstruct critical views as they mature
- Provide a neutral visual background to the intersection where possible Shall have distinct features than the adjacent to mark the entrance
- Plants should help focus the view on the intersection
- Shrubs should be avoided within the appropriate sight triangle at an intersection

The roads considered under DPR-5 have very little open space to properly landscape. And many of the roads are having less RoW. In view of this only shrubs are proposed in the medians where possible.

The details of various Landscape Proposals along Proposed Roads is provided at Section 11

3.1.5 Centralized street lighting control

"Conversion of Conventional Street Lights into LED with Smart Lighting Solutions" is one of the projects under MSC with an objective of reducing energy consumption as well as to reduce impact on environment by conventional lamps. The existing street lights are proposed to be converted into LED on PPP basis under a separate project.

Smart LED street lighting system adopts centralized control system which will result in further saving of electrical energy. This system offers following Merits –

- Central control, fault detection
- Generation of burn hours reports
- Automatic operation with astronomical timers
- Manual operation from a central location through GPRS / GSM system
- Dimming operation
- Remote metering
- Voltage stabilization

Energy consumed by the LED lighting is much less as compared to the sodium vapour lighting. This will reduce the energy bill of street lights to great extent.

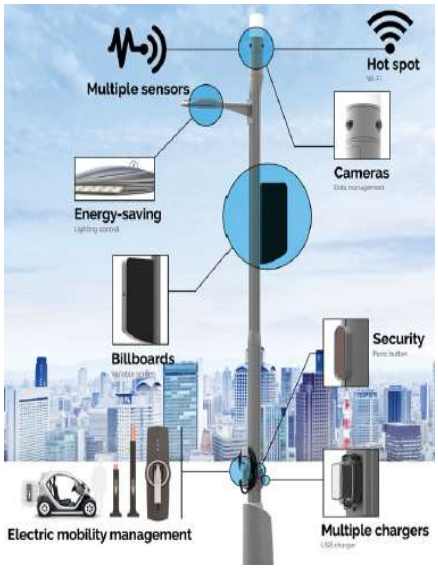
The 9 m lighting poles are provided only in the median. To illuminate the footpaths, 4 m high lighting poles with 40 w LED lighting fixtures has been considered at an interval of 10 m

SMART STREET LIGHTING SOLUTIONS PROPOSED UNDER SMART ROADS WILL BE TAKEN UP UNDER SEPARATE TENDER FOR LED STREET LIGHTS PPP PROJECT COMPONENTS. FOOTPATH LIGHTING IS PART OF THIS TENDER

3.1.6 IT/ICT Elements

The following IT/IC Elements are considered along the Bus Shelter and Smart Pole

- IT/ICT components in Smart Bus Shelter
  - CCTV (dome camera)
  - Wifi Access Point
  - Display units
- IT/ICT component in Smart Pole at Traffic Junction
  - Wifi Access Point
  - Environment Sensor
  - Possible push button for the pedestrian crossing
- PTZ CCTV at Junction



3.2 Intelligent Traffic Management and Road Surveillance

ITMS is distributed across / coupled with mainly, Intelligent Transport System and Road Surveillance:

3.2.1 Intelligent Transport System (ITS)

The Intelligent Transport along the proposed roads will have the following features

1. **Vehicle Tracking (Buses) System**

The Buses with mounted GPS will be tracked by the Vehicle Tracking System so that their movement data can be fed to the ITS and the information can be disseminated to the Public Mobility App and Display at the Bus Shelters

2. **Information on Bus Transport**

The Vehicle Tracking System + Road Surveillance System + the Schedule fed in the Database of ITS will relay the information for the Public on the next scheduled buses on the particular route, the delay in the buses running, next available bus to arrive, traffic congestion on particular routes etc.

3. **Portable Ticketing**

The bus tickets can be purchased either online or at bus-shelters. Online payment to be availed as well

4. **Public Mobility App**

The bus schedule, the buses actual movements and available buses on the routes, to be made available for the passengers in the app or in the bus-shelter

5. **Synchronized Signaling**

Green Corridor Creation for Disaster Mitigation / Emergency Response Team / Medical Emergency

3.2.2 Road Surveillance

1. **Traffic Rule Violation Detection**

- Red Light Violation
- Speed Violation
- e-Challan (if integrated with RTO Database)

The traffic violation detection by the Camera's to be analysed by the Video Analytics Software in the CCC and the ANPR to detect the vehicle number of the vehicles that violate the traffic rule. The identified vehicle number details then to be fetched from the RTO / Vahan -Sarathi

systems and e-Challan to be sent to the contact details of the person against whose name the vehicle is registered.

2. **Automatic Number Plate Recognition**

3. **Object Detection (for suspicious objects)**

If any object is detected to be static / suspicious (based on the rules configured in the Video Analytics Software system) then the alert to be sent to the competent authority defined in the Standard Operating Procedure for such events.

4. **Road Disaster Alert**

If any accident is detected by the camera or sensitive situation is SOSed by citizen(s) then the alert to be sent to the competent authority defined in the Standard Operating Procedure for such events. The subsequent alert to Emergency Response Team to receive as well

ITMS AND IT/ICT COMPONENTS PROPOSED UNDER SMART ROADS WILL BE TAKEN UP UNDER SEPARATE TENDER FOR ICT COMPONENTS

3.3 TRAFFIC MANAGEMENT PLAN

3.3.1 Traffic Management during Construction and Upgradation Works

The basic upgradation of roads are considered for development which are listed below

Table 64 Road Upgradation Features

Rd. No	Road	Type of Pavement	Quality of Pavement	Road Upgradation
7a	**Milagres Cross Rd.**	Flexible	Good	Conversion to Rigid Pavement, Utility development
7c	**Attavara-Nandigudda Rd.**	Rigid	Good	Utility development Only
8	**New Balmatta Rd.**	Flexible	Good	Conversion to Rigid Pavement, Utility development
10	**Kudumbi Garden (DBS) Road**	Rigid	Poor	Utility development only
15a	**Azizuddin Road**	Rigid	Good	Utility development Only
15b	**Jumma Masjid - Old Port Rd.**	Rigid, Flexible	Poor	Utility development and in some portion Conversion Flexible to Rigid Pavement
19a	**Arya Samaj Rd.**	Paver	Good	Conversion to Rigid Pavement, Utility development
19b	**Balmatta Road**	Rigid	Good	Utility development Only
20	**Bengre Ferry Rd.**	Flexible	Good	Conversion to Rigid Pavement, Utility development

3.3.2 Milagres Cross Road

At present, 7837 vehicles (10254 PCUs) ply on Milagres Cross Road. Northward traffic can be diverted towards Avery Jn (Falnir Road) from Mother Theresa Road..

Following table gives the composition of peak traffic of Mother Theresa Road Section A.

Table 65 Modal Split of Milagres Cross Road

2 Wheeler	3 Wheeler	Car	LCV	Bus/Truck	Other (MT)	Other (NMT)	Total Vehicles	Total PCUs
2,991	3,083	1,598	76	85	0	4	7,837	10,254

3.3.3 New Balmatta Road

At present, 12687 vehicles (15789 PCUs) ply on New Balmatta Road. Northward traffic can be diverted towards DBS Road and Southward traffic can also be diverted towards DBS Road.

Following table gives the composition of peak traffic of Mother Theresa Road Section A.

Table 66 Modal Split of New Balmatta Road

2 Wheeler	3 Wheeler	Car	LCV	Bus/Truck	Other (MT)	Other (NMT)	Total Vehicles	Total PCUs
4,913	4,321	3,257	139	41	0	16	12,687	15,789

3.3.4 Jumma Masjid Port Road

At present, 1962 vehicles (1741 PCUs) ply on DBS Road. Northward traffic can be diverted towards Azizuddin Road and Southward traffic can be diverted towards MPT Road or Bunder Road or the vice versa.

Following table gives the composition of peak traffic of Mother Theresa Road Section A.

Table 67 Modal Split of Port Road

2 Wheeler	3 Wheeler	Car	LCV	Bus/Truck	Other (MT)	Other (NMT)	Total Vehicles	Total PCUs
1,302	367	139	125	24	0	5	1,962	1,741

3.3.5 Attavara Road, Jumma Masjid Road, Balmatta Road, Azizuddin Road, Bengre Ferry Road, Arya Samaj Road

The above mentioned roads are already concrete roads and are not needed for any pavement development. Even the quality of the roads are in good condition so mostly repairing works are also minimal. As part of up gradation to make smart roads, it is proposed to carry joint filling and utility development improvements in carriageway of these roads.

For Masjid Road and Ferry Road, Utility development is proposed and in some portions conversion of surface from Flexible to Rigid Pavement is proposed.

Since these roads are predominantly busy, repairs works will be done at night time with proper safety and barricades. These roads will be open for public use in daytime.

3.3.6 Safety Measure during Construction

Lanes Closure is the operation in which one or more traffic lanes and any adjacent shoulder are closed to traffic, in case of a multi-lane Roads, for carrying out the necessary repair/up gradation works. Guidelines provided by **(IRC: SP55 GUIDELINES ON TRAFFIC MANAGEMENT IN WORK ZONES)** needed to be followed for safe traffic movement during construction.

For road, having less than 20 trucks per hour and speed limit less 50 km/h or less, following figure gives the arrangement required at construction zone.

Length of the works from the start of the lead-in taper to the end of the exit taper should not be more than 50 meters .Drivers approaching from either direction can see both the ends of the site.

Subsequent paragraphs and figure explain the arrangement can be applicable at Junction during Construction

The regulatory signs to be used in work zones are subdivided as normal regulatory signs and Work zones specific regulatory sign. Regulatory signs are to instruct road users of traffic laws or regulations and to indicate the applicability of legal requirements that would not otherwise be apparent.

For ensuring legibility and emphasis at night, the signs shall be retro-reflective of at least Grade Type III, i.e. high intensity grade conforming to 801 of Specifications for Roads & Bridges, Ministry of Road Transport and Highways.

The material shall be smooth, sealed outer surface or illuminated to depict the same shape and similar color for both day and night. Sign illumination may be either internal or external and the signboards may be made of rigid or flexible material.

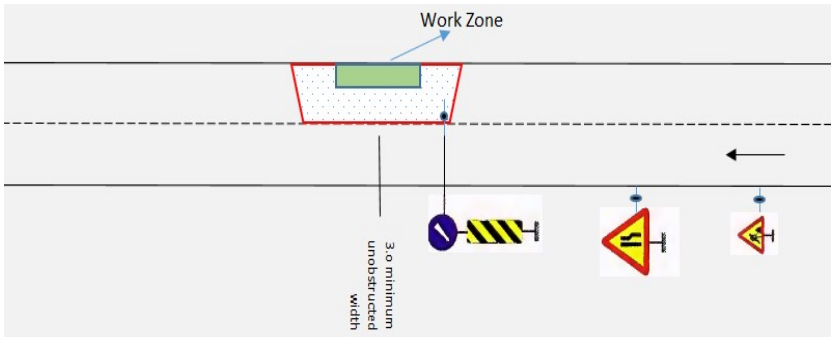


Figure 46 Traffic Control System along the road during Construction

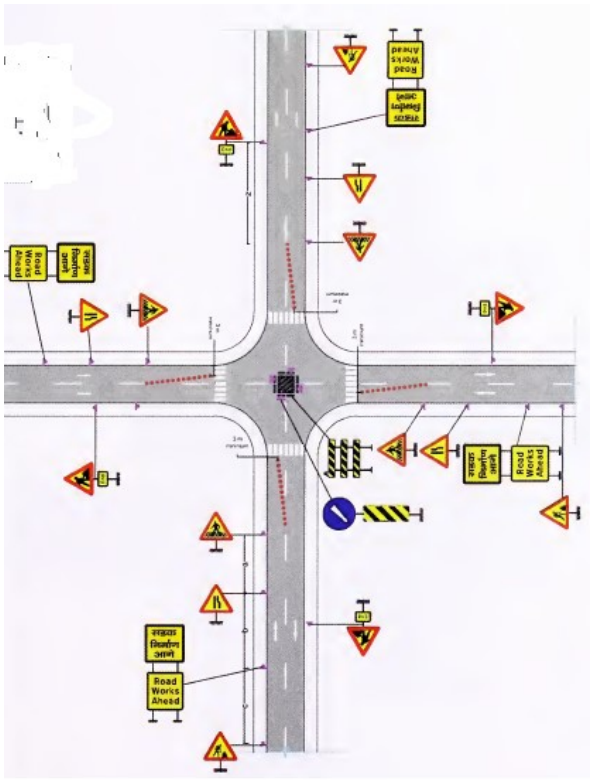


Figure 47 Traffic Control System along the road during Construction

3.3.7 Conclusion

As mentioned above lane closure alternately can adequately handle traffic at on these roads during construction period. Nighttime construction is preferred alternative for up gradation works at other road on the loop.

IRC 55 guideline diagrams as given in this section need to be adhered for safe traffic movement.

Chapter 4 TIMELINE FOR EXECUTION

The Total timeline for project are divided into 3 broad categories:

4.1 Construction Phase

The construction phase is considered as **18 months**

4.2 Defect Liability

The Defect Liability period is considered as **12months**

4.3 Maintenance Period

The Maintenance Period is considered as **36 months** from date of construction completion

Note: Detailed schedule shall be during the final DPR and RFP Stage

Chapter 5 MONITORING AND EVALUATION

The key components under smart road to be monitored are listed below:

- Development and strengthening of carriage way with uniform lane widths and geometric designs of roads and junctions as per street design standards.
- Development of footpath and cycle lanes wherever feasible - with uniform footpath widths, pedestrian friendly ways and barrier-free designs.
- Construction of utility ducts for water, sewerage, drainage, power, gas and optical fibre cables (OFC), wherever essential – with suitable provision for O&M.
- Construction bus bays, auto bays and on-street parking wherever essential.
- Beautification and landscaping including greenery and carbon sinking,
- Provision of smart street furniture and public utilities such as including communicative signage, lane marking. (passenger shelters, bus stops, parking, green toilets, first aid care, traffic police booth etc), public leisure spaces etc.
- Smart street-poles with LED lights, CCTV and various sensors as per city requirement.
- Accessibility standards as prescribed by the MoUD, etc.
- Particular focus on safety of women, children, elderly, etc

Risk assessment and mitigation strategy: Any project development is averse to various types of risks during the life cycle of the project. Identifying these risks and allocating them to the stakeholders who are able to address them the best is the most acceptable form of mitigation.

In this context, key risk associated with the project along with assessment is presented below:

Table 68 Risks Mitigation Strategies

Sl. No	Risk Type	Degree (High/ Moderate/ Low)	Mitigation Strategy
1	Construction Phase Risks		
1a	Land Acquisition Delay	Low	Upgradation of roads does not involve any land acquisition. Therefore there is no land acquisition risk for this sub-project
1b	Delay in receipt of statutory approvals to the project	Moderate	The statutory requirements of the project would include approval of traffic management plan and for utility shifting. MCC can provide the requisite facilitation to MSCL for obtaining the necessary approvals for the proposed project.
1c	Time and Cost Over runs during construction	Moderate	The project involves upgradation of urban roads wherein no engineering or structural challenges are foreseen. PMC would monitor the overall progress of the project and suggest appropriate remedies/ actions to be taken by MSCL.
2	Regulatory risk		
	Change in law/ policy	Low	Change in policies leading to material adverse

			impact on the urban infrastructure sector is not envisaged. The present policies in force are expected to pave the way for Smart City development over the long term.
3	Force Majeure.		
	Act of God (Fire, earthquake, etc)	Low	Such risks shall be mitigated through insurance cover. The contractor would be mandated to keep in force insurance covering all project assets during the construction and contract liability phase for insurable events.

Chapter 6 COST ESTIMATES

The section of the report deals with the Cost Estimates for DPR-5 Smart Roads

6.1 Assumptions

- SOR rates as per Karnataka PWD SOR-Mangalore Circle (SOR 2018-19)
- 10% weightage has been added to SOR rates of Mangalore Circle PWD Circle
- Non SOR Items based on Rate Analysis OR on Vendor Quotations
- Landscaping rates as per Karnataka PWD and As per EOI.
- Water Supply Package are to be executed under ADB Project and as separate package, hence cost not to be considered in smart road tender cost
- UGD (sewer network) Package will be floated as separate tender, hence cost not to be considered in smart road tender cost
- LED Street Light Package will be floated as separate tender, hence cost not to be considered in smart road tender cost
- ICT Package will be floated as separate tender, hence not to be considered in smart road tender cost

6.2 Summary of Estimate

Summary of the estimate is as stated in table below:

Table 69 Smart Road Package- 5 – Summary of Estimate

Sr. No.	Description	Cost In INR
1	Road and Other Works	37,34,90,066
2	Street Lighting	64,63,562
3	Landscape Work	22,38,546
	Construction Cost Sub Total	**38,21,92,174**
	GST @ 12% -Civil Construction Cost (Refer 1.0 Abstract)	4,40,83,122
	Provision for Third Party Damages and Maintenance at 1st Year(DLP-	28,83,930
	GST @12% on DLP Cost Items (Refer 5.1 Abstract)	2,65,467
	Maintenance Cost of 2nd,3rd and 4th Year	1,21,84,243
	GST @12% on Maintenance Cost	11,81,659
	Escalation and Tender Premium @10%	382,19,217
	Add 3% Contingency	114,65,765
	Miscellaneous and Rounding off	24,423
	Grand Total	**49,25,00,000**

6.3 Detailed BOQ

Detailed BOQ has been enclosed as Volume III of the Detailed Project Report

ANNEXURES I – LIST OF DRAWINGS

No.	Drawing no	Drawing Title	No of Sheets
1	WTE_2292_04_R_2.01	PLAN AND PROFILE OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	1
2	WTE_2292_04_R_2.02	PLAN AND PROFILE OF NEW BALMATTA ROAD (ROAD NO. 8)	1
3	WTE_2292_04_R_2.03	PLAN AND PROFILE OF ARYA SAMAJ ROAD (ROAD NO. 19b)	1
4	WTE_2292_04_R_2.04	PLAN AND PROFILE OF JUMMA MASJID OLDPORT ROAD (ROAD NO.15b)	1
5	WTE_2292_04_R_2.05	PLAN AND PROFILE OF BENGRE FERRY ROAD (ROAD NO.20)	1
6	WTE_2292_04_R_3.01	ROAD SIGNAGES - PLAN AND ROAD MARKING OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	1
7	WTE_2292_04_R_3.02	ROAD SIGNAGES - PLAN AND ROAD MARKING OF ATTAVARA NANDIGUDA ROAD (ROAD NO. 7c)	5
8	WTE_2292_04_R_3.03	ROAD SIGNAGES - PLAN AND ROAD MARKING OF NEW BALMATTA ROAD (ROAD NO. 8)	3
9	WTE_2292_04_R_3.04	ROAD SIGNAGES - PLAN AND ROAD MARKING OF KUDUMBI GARDEN (DBS) ROAD (ROAD NO. 10)	2
10	WTE_2292_04_R_3.05	ROAD SIGNAGES - PLAN AND ROAD MARKING OF ARYA SAMAJ ROAD (ROAD NO. 19a)	3
11	WTE_2292_04_R_3.06	ROAD SIGNAGES - PLAN AND ROAD MARKING OF BALMATTA ROAD (ROAD NO. 19b)	2
12	WTE_2292_04_R_3.07	ROAD SIGNAGES - PLAN AND ROAD MARKING OF AZIZUDDIN ROAD (ROAD NO.15a)	3
13	WTE_2292_04_R_3.08	ROAD SIGNAGES - PLAN AND ROAD MARKING OF JUMMA MASJID-OLD PORT ROAD (ROAD NO.15b)	4
14	WTE_2292_04_R_3.09	ROAD SIGNAGES - PLAN AND ROAD MARKING OF BENGRE FERRY ROAD (ROAD NO.20)	5
15	WTE_2292_04_R_4.01	ROAD SIGNAGES AND MARKING DETAILS	1
16	WTE_2292_04_R_5.01	PROPOSED CROSS SECTION OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	3
17	WTE_2292_04_R_5.02	PROPOSED CROSS SECTION OF ATTAVARA NANDIGUDA ROAD (ROAD NO. 7c)	20
18	WTE_2292_04_R_5.03	PROPOSED CROSS SECTION OF NEW BALMATTA ROAD (ROAD NO. 8)	11
19	WTE_2292_04_R_5.04	PROPOSED CROSS SECTION OF KUDUMBI GARDEN (DBS) ROAD (ROAD NO. 10)	8
20	WTE_2292_04_R_5.05	PROPOSED CROSS SECTION OF ARYA SAMAJ ROAD (ROAD NO. 19a)	12
21	WTE_2292_04_R_5.06	PROPOSED CROSS SECTION OF BALMATTA ROAD (ROAD NO. 19b)	6
22	WTE_2292_04_R_5.07	PROPOSED CROSS SECTION OF AZIZUDDIN ROAD (ROAD NO.15a)	15
23	WTE_2292_04_R_5.08	PROPOSED CROSS SECTION OF JUMMA MASJID-OLD PORT ROAD (ROAD NO.15b)	21
24	WTE_2292_04_R_5.09	PROPOSED CROSS SECTION OF BENGRE FERRY ROAD (ROAD NO.20)	23
25	WTE_2292_05_R_6.01	PROPOSED UTILITY SERVICES OF MILAGRES CROSS ROAD. (ROAD NO. 7a)	1
26	WTE_2292_05_R_6.02	PROPOSED UTILITY SERVICES OF ATTAVARA NANDIGUDDA ROAD (ROAD NO. 7c)	5
27	WTE_2292_05_R_6.03	PROPOSED UTILITY SERVICES OF NEW BALMATTA ROAD (ROAD NO. 8)	3

28	WTE_2292_05_R_6.04	PROPOSED UTILITY SERVICES OF KUDUMBI GARDEN (DBS) ROAD (ROAD NO. 10)	**2**
29	WTE_2292_05_R_6.05	PROPOSED UTILITY SERVICES OF ARYA SAMAJ ROAD (ROAD NO. 19a)	**3**
30	WTE_2292_05_R_6.06	PROPOSED UTILITY SERVICES OF BALMATTA ROAD (ROAD NO. 19b)	**2**
31	WTE_2292_05_R_6.07	PROPOSED UTILITY SERVICES OF AZIZUDDIN ROAD (ROAD NO.15a)	**3**
32	WTE_2292_05_R_6.08	PROPOSED UTILITY SERVICES OF JUMMA MASJID-OLD PORT ROAD (ROAD NO.15b)	**4**
33	WTE_2292_05_R_6.09	PROPOSED UTILITY SERVICES OF BENGRE FERRY ROAD (ROAD NO.20)	**5**

ANNEXURES II – SPECIFICATIONS

ALL THE WORKS TO BE EXECUTED AS PER RELEVANT MORTH, IRC, KSRB DETAILED SPECIFICATION & NATIONAL BUILDING CODE & AS PER RELEVANT BUREAU OF INDIAN STANDARD SPECIFICATIONS

LANDSCAPE DETAILS AS PER SPECIFICATIONS MENTIONED IN DRWINGS FOR PLANTING DETAIL

SOME SPECIFIC SPECIFICATIONS CONSIDERED ARE AS MENTIONED BELOW

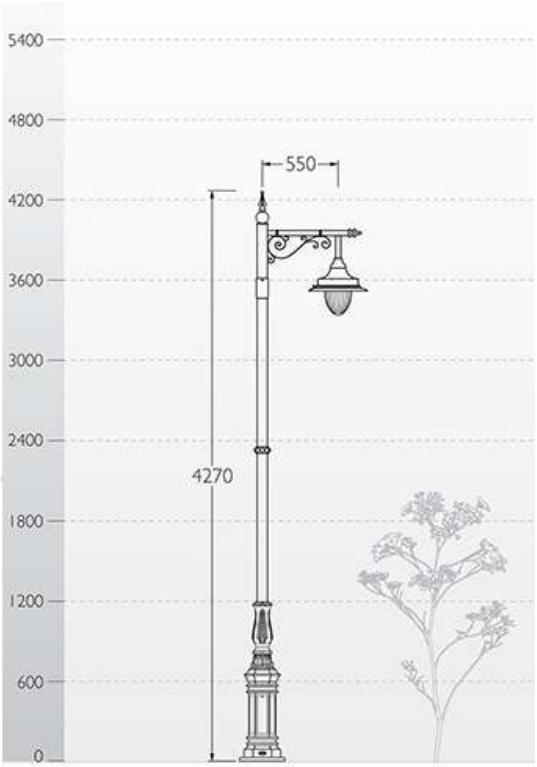
LIGHT FIXTURE FOR FOOTPATH

Make : K-LITE

MODEL : VICENT LIGHTING POLE

Code : KP-450

HT : 4270MM



PERMEABLE ECO-FRIENDLY PAVERS DETAILS

PAVER OPTION FOR CAR PARK AREA: UNILOCK - ECO-OPTILOC

Description:

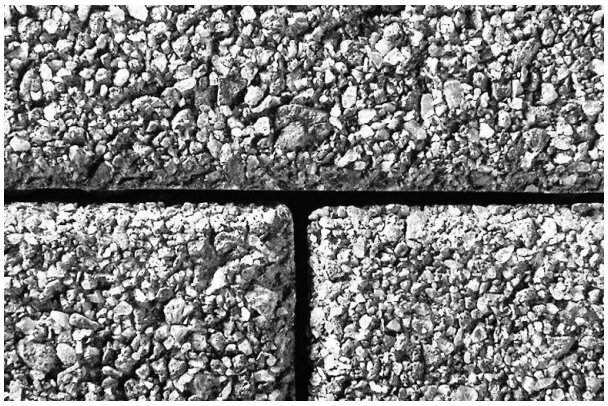


Figure 1 washed finish

This paver has gained world-wide acceptance as the paver-of-choice for performance, and as an environmental solution for drainage. Only the patented "L" shaped design allows you to achieve a superior lock-up that can withstand even the heaviest of loads residentially and commercially. The innovative design creates small voids between the pavers providing drainage into the sub-base.

Standard size: 26 cm x 26 cm x 8 cm i.e. 10.25" X 10.25" X 3.125".

Handling and Installation

- A protective pad is recommended when doing the final paver compaction. These products canbe installed mechanically or by hand.
- Jointing Material and Joint Stabilization
- Use only select graded stone chips for void filling UnilockEasyPro
- Product may be sealed but it is not absolutely requiredUnilock, Unicare, Surebond, BP Pro and Techniseal sealers can be used.
- Select type for desired aesthetics.
- Product must be cleaned before sealing
- Cleaners – Any paver cleaner may be used for colour restoration or general cleaning. Follow manufacturer's dilution rates and application procedures.

PAVER OPTION FOR FOOTPATHS: **BASANT BETONS - ECOLOC**

Description:

Ecoloc permeable interlocking concrete pavers are aimed to reduce storm water runoff. It is an ideal choice for driveways & parking lots. They can also be used for heavy duty applications for ports and storage yards. They form good usage for pavement in all sorts of landscapes including residential dwellings for water harvesting, as these offer great environmental benefits of being able to infiltrate water through the pavement surface into the ground below.

- Maximizes ground water recharge enabling water harvesting for reuse.

- Reduces nonpoint source pollutants in storm water thereby mitigating impact on surrounding surface waters and also would reduce downstream flooding and earth erosion.
- Facilitates efficient land use planning and productive use of land for greater financial benefits offering great help where land prices are high.
- To lessen project costs by reducing or eliminating retention and drainage systems.
- Useful in designing variety of storm water management requirements.

Dimensions:

Thickness: 3 1/8 inches (80mm)

Outside Length : 8 7/8 inches (225mm)

Inside Length : 4 ½ inches (112.5mm)

Pavers Per Sft: 2.41

Percentage of drainage "opening" area per sft : 12.18%

Figure 2 Terracotta 70%-grey 30%

PEDESTRIAN SIGNAL:

Salient features of Traffic Signal Heads

- Special Quality LEDs for uniform high output for extended period and much longer overall life
- Uniformly spaced LEDs give larger and uniform view for dot matrix & high Flux
- Light Intensity & Colour wavelength of LEDs are measured at our optical lab to comply with International specifications
- Complies minimum viewing angel specifications
- The Assemblies use no reflector and LEDs have no colour in off condition eliminates sun phantom effects.
- Available in different voltage versions in AC and DC
- Optical unit and housing protected to IP65/IP54
- Better than 0.9 power factor in AC mains version
- Intensity loss on single LED failure less than 2%
- CE Certified & in compliance with BSEN12368

Pedestrian Traffic Light

ROADSIDE DUSTBIN:

Product Name	Outdoor Dustbin Steel 55L
Size	55liters
Capacity	55L /75L /100L
Material	SS 304 Steel

BOLLARDS:

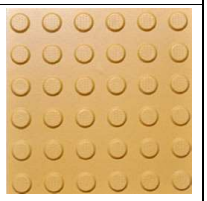
- 304/ 316 grade polished stainless steel
- Machined flat cap
- Optional cover skirts available
- Versatile products for decorative covers, removable traffic parking control, bike parking and safety security

Features

1. Higher resistance to corrosion
2. Greater resistance to pitting and staining
3. Low Maintenance
4. Recyclable

TACTILE PAVING

Table 0-1: Tactile Paving

Parameter	*Specification*	*Area*	*Photo*
Directional Tile	Size: 300x 300 x 60 mm Colour: Yellow Grade of Concrete: M-30	356 sq.m.	
Stop tile	Size: 300x 300 x 60 mm Colour: Yellow Grade of Concrete: M-30	100 sq.m.	

ANNEXURES III – DESIGN CALCULATIONS FOR STORM WATER DRAINAGE

ROAD-7a																
Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Manning's n	Width(m)	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-504	7a	MH-527	29.89	MH-528	28.37	26.4	40	0.013	0.6	2.8	1101.66	40.4	30.49	29.85	0.6	1.48
CO-505	7a	MH-528	28.37	MH-30	22.87	137.5	25	0.013	0.6	3.3	1381.01	32.1	29.85	24.21	1.48	1.34

ROAD-7C																
Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Manning's n	Width(m)	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-64	7c	MH-67	15.14	MH-68	12.82	127.7	55	0.013	0.6	2.8	1101.66	40.4	17.65	15.43	2.51	2.61
CO-65	7c	MH-68	12.82	MH-69	9.23	125.6	35	0.013	0.6	3.3	1381.01	32.1	15.43	11.8	2.61	2.57
CO-66	7c	MH-69	9.23	MH-70	5.84	67.9	20	0.013	0.6	4.03	1826.9	24.2	11.8	8.69	2.57	2.85
CO-67	7c	MH-70	5.84	MH-71	5.26	34.8	60	0.013	0.6	2.71	1054.76	41.9	8.69	7.05	2.85	1.79
CO-68	7c	MH-71	5.26	MH-72	4.76	29.4	60	0.013	0.6	2.71	1054.76	41.8	7.05	5.69	1.79	0.93
CO-69	7c	MH-72	4.76	MH-73	3.97	39.8	50	0.013	0.6	2.89	1155.43	38.1	5.69	4.61	0.93	0.64
CO-70	7c	MH-73	3.97	O-9	3.24	36.5	50	0.013	0.6	2.89	1155.43	38.1	4.61	3.85	0.64	0.61
CO-80	7c	MH-85	17.12	MH-86	16.79	73.8	225	0.013	0.6	1.48	544.68	51.9	18.29	17.96	1.17	1.17
CO-81	7c	MH-86	16.79	MH-87	15.89	40.5	45	0.013	0.6	2.65	1217.93	23.1	17.96	17.06	1.17	1.17
CO-82	7c	MH-87	15.89	MH-81	15.1	31.7	40	0.013	0.6	2.76	1291.81	21.7	17.06	15.71	1.17	0.61
CO-78	7c	MH-82	13.22	MH-83	12.85	22.3	60	0.013	0.6	3	1054.76	63.3	14.93	13.95	1.71	1.1
CO-77	7c	MH-81	13.61	MH-82	13.22	23.6	60	0.013	0.6	3	1054.76	63.4	15.71	14.93	2.1	1.71
CO-79	7c	MH-83	12.85	O-10	12.4	33.6	75	0.013	0.6	2.75	943.41	70.8	13.95	13.01	1.1	0.61

ROAD-8																
Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Width (m)	Manning's n	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-35	8	MH-38	36.58	MH-39	31.54	75.6	15	0.6	0.013	3.28	2109.52	8.2	38.81	32.15	2.23	0.61
CO-36	8	MH-39	31.54	MH-40	30.58	33.5	35	0.6	0.013	2.47	1381.01	12.4	32.15	31.24	0.61	0.66
CO-37	8	MH-40	30.58	MH-41	30.33	31	125	0.6	0.013	1.6	730.76	23.5	31.24	30.99	0.66	0.66
CO-38	8	MH-41	30.33	MH-42	30.01	48.9	150	0.6	0.013	1.5	667.09	25.7	30.99	30.63	0.66	0.62

CO-39	8	MH-42	30.01	MH-43	29.67	99.9	300	0.6	0.013	1.17	471.7	36.2	30.63	32.21	0.62	2.54
CO-40	8	MH-43	29.67	MH-44	29.36	95.4	300	0.6	0.013	1.16	471.7	35.9	32.21	31.67	2.54	2.31
CO-41	8	MH-44	29.36	MH-45	29.26	28	300	0.6	0.013	1.16	471.7	35.7	31.67	30.65	2.31	1.39
CO-42	8	MH-45	28.68	MH-46	27.15	46.1	30	0.6	0.013	2.58	1491.66	11.3	30.65	29.08	1.97	1.93
CO-43	8	MH-46	27.15	MH-47	27.09	17	300	0.6	0.013	1.16	471.7	35.6	29.08	28.52	1.93	1.43
CO-44	8	MH-47	27.09	MH-48	26.98	34.7	300	0.6	0.013	1.16	471.7	35.5	28.52	28.04	1.43	1.06
CO-45	8	MH-48	26.98	MH-37	26.86	34.8	300	0.6	0.013	1.16	471.7	35.5	28.04	27.47	1.06	0.61
CO-46	8	MH-37	24.09	MH-49	24.08	9.3	1000	0.6	0.013	0.9	434.6	76	27.47	27.49	3.38	3.41
CO-47	8	MH-49	24.08	MH-50	23.73	14.2	40	0.6	0.013	2.98	1291.81	28.3	27.49	27.12	3.41	3.39

ROAD-15a

Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Manning's n	Width(m)	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-182	15a	MH-177	3.01	MH-178	2.74	27.2	100	0.013	0.6	1.52	817.01	13.2	4.92	4.06	1.91	1.32
CO-192	15a	MH-178	2.74	O-19	2.14	59.8	100	0.013	0.6	1.52	817.01	13.1	4.06	2.75	1.32	0.61
CO-481	15a	MH-494	3.01	MH-495	2.73	28.1	100	0.013	0.6	0.89	817.01	2.8	4.92	4.06	1.91	1.33
CO-482	15a	MH-495	2.73	O-48	2.14	58.7	100	0.013	0.6	0.88	817.01	2.8	4.06	2.75	1.33	0.61
CO-190	15a	MH-186	6.98	MH-180	5.41	62.8	40	0.013	0.6	2.89	1291.81	25.5	8.27	6.62	1.29	1.21
CO-184	15a	MH-180	5.41	MH-179	2.05	151.1	45	0.013	0.6	2.77	1217.93	27	6.62	3.33	1.21	1.28
CO-195	15a	MH-179	2.05	O-20	1.55	170	-340	0.013	0.6	1.31	443.09	73.7	3.33	2.83	1.28	1.28
CO-187	15a	MH-182	7.55	MH-183	7.22	80.5	240.274	0.013	0.6	1.29	527.08	32.6	8.16	8.34	0.61	1.12
CO-188	15a	MH-183	7.22	MH-184	6.78	43.1	100	0.013	0.6	1.75	817.01	20.9	8.34	8.01	1.12	1.23
CO-189	15a	MH-184	6.78	O-21	5.81	97.4	100	0.013	0.6	1.75	817.01	20.8	8.01	6.42	1.23	0.61
CO-483	15a	MH-497	4.88	MH-498	4.23	64.4	100	0.013	0.6	1.48	817.01	12.1	8.27	6.62	3.39	2.39
CO-484	15a	MH-498	4.23	MH-499	3.03	120.6	100	0.013	0.6	1.47	817.01	12	6.62	3.85	2.39	0.82
CO-485	15a	MH-499	3.03	MH-500	2.72	30.5	100	0.013	0.6	1.46	817.01	11.6	3.85	3.33	0.82	0.61
CO-486	15a	MH-500	2.72	O-49	2.22	169.2	335.671	0.013	0.6	0.96	445.94	21.2	3.33	2.83	0.61	0.61

ROAD-15b

Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Manning's n	Width(m)	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-467	15b	MH-480	1.23	O-46	0.87	79.8	226.136	0.013	0.6	1.32	543.31	32.1	1.84	1.48	0.61	0.61
CO-469	15b	MH-485	0.82	MH-486	0.58	23.8	100	0.013	0.6	1.67	817.01	17.9	2.19	1.19	1.37	0.61
CO-470	15b	MH-486	0.58	MH-487	0.52	62.6	1000	0.013	0.6	0.73	258.36	56.4	1.19	1.23	0.61	0.71

CO-473	15b	MH-487	0.52	MH-489	0.49	30.4	1000	0.013	0.6	0.72	258.36	55.3	1.23	1.62	0.71	1.13
CO-474	15b	MH-489	0.49	MH-488	0.42	62	1000	0.013	0.6	0.72	258.36	54.9	1.62	1.42	1.13	1
CO-472	15b	MH-488	0.42	MH-483	0.39	32	1000	0.013	0.6	0.72	258.36	53.9	1.42	1.46	1	1.07
CO-468	15b	MH-483	0.39	O-47	0.36	28.4	-1000	0.013	0.6	0.72	258.36	53.4	1.46	1.53	1.07	1.17
CO-495	15b	MH-514	2.9	MH-515	2.19	88.4	439.377	0.013	0.6	0.61	389.77	7.8	3.51	3	0.61	0.81
CO-496	15b	MH-515	2.19	MH-365	1.19	76.4	410.613	0.013	0.6	0.61	403.19	7.2	3	2.33	0.81	1.14
CO-499	15b	MH-365	1.19	MH-518	1.34	4.2	100	0.013	0.6	2.04	817.01	35.7	2.33	2.3	1.14	0.96
CO-497	15b	MH-516	-0.61	MH-517	-0.7	87.6	1000	0.013	0.6	0.87	434.6	67.6	0	0	0.61	0.7
CO-498	15b	MH-517	-0.7	MH-518	-0.96	75.9	294.161	0.013	0.6	1.37	476.36	62.2	0	0	0.7	0.96
CO-494	15b	MH-512	3.48	O-53	2.89	77.3	131.935	0.013	0.6	0.63	711.3	1.6	4.09	3.5	0.61	0.61
CO-503	15b	MH-524	3.48	O-56	2.89	76.6	130.74	0.013	0.6	1.58	714.54	22.8	4.09	3.5	0.61	0.61
CO-501	15b	MH-521	3.62	MH-522	3.42	32.5	164.914	0.013	0.6	1.14	636.21	11.6	4.23	4.06	0.61	0.64
CO-502	15b	MH-522	3.42	O-55	2.86	56.2	100	0.013	0.6	1.34	817.01	8.9	4.06	3.47	0.64	0.61
CO-492	15b	MH-509	3.62	MH-510	3.35	30.9	113.882	0.013	0.6	0.81	765.6	2.6	4.23	3.96	0.61	0.61
CO-493	15b	MH-510	3.35	O-52	2.86	56.5	115.83	0.013	0.6	0.8	759.13	2.6	3.96	3.47	0.61	0.61
CO-500	15b	MH-519	2.96	O-54	2.86	32.4	323.98	0.013	0.6	1.13	453.91	35	3.57	3.47	0.61	0.61
CO-491	15b	MH-507	2.96	O-51	2.86	32	319.572	0.013	0.6	0.38	457.03	1.4	3.57	3.47	0.61	0.61
CO-490	15b	MH-526	2.15	MH-505	1.9	24.8	-100	0.013	0.6	2.01	817.01	33.8	2.84	2.51	0.69	0.61
CO-488	15b	MH-504	1.56	MH-503	1.39	39	-232.638	0.013	0.6	1.47	535.66	51	2.17	2.02	0.61	0.63
CO-489	15b	MH-505	1.9	MH-504	1.56	44.3	-130.427	0.013	0.6	1.83	715.39	38.5	2.51	2.17	0.61	0.61
CO-487	15b	MH-503	1.39	O-57	1.16	23.2	-100	0.013	0.6	2	817.01	33.2	2.02	1.77	0.63	0.61
CO-221	15b	MH-215	16.34	MH-216	15.98	101.3	280	0.013	0.6	0.72	488.26	7	17.57	17.21	1.23	1.23

ROAD-19																
Label	**Road Name**	**Start Node**	**Invert (Start) (m)**	**Stop Node**	**Invert (Stop) (m)**	**Length (Scaled) (m)**	**Slope (Calculated) (1/S)**	**Manning's n**	**Width(m)**	**Velocity (m/s)**	**Capacity (Full Flow) (L/s)**	**Flow / Capacity (Design) (%)**	**Elevation Ground (Start) (m)**	**Elevation Ground (Stop) (m)**	**Depth (Start)m**	**Depth (Stop)m**
CO-163	19	MH-160	39.47	MH-161	37.04	24.3	10	0.013	0.6	4.44	2583.63	11	41.01	38.35	1.54	1.31
CO-164	19	MH-161	37.04	MH-162	35.84	29.9	25	0.013	0.6	3.26	1634.03	17.4	38.35	37.01	1.31	1.17
CO-165	19	MH-162	35.84	MH-163	34.6	43.4	35	0.013	0.6	2.9	1381.01	20.6	37.01	35.73	1.17	1.13
CO-166	19	MH-163	34.6	MH-164	33.56	20.9	20	0.013	0.6	3.52	1826.9	15.5	35.73	34.67	1.13	1.11
CO-167	19	MH-164	33.56	MH-165	31.88	33.5	20	0.013	0.6	3.51	1826.9	15.5	34.67	32.94	1.11	1.06
CO-168	19	MH-165	31.88	MH-166	29.52	47.3	20	0.013	0.6	3.51	1826.9	15.5	32.94	30.28	1.06	0.76
CO-169	19	MH-166	29.52	MH-167	28.92	68.4	115	0.013	0.6	1.89	761.87	37.1	30.28	29.69	0.76	0.77
CO-170	19	MH-167	28.92	MH-168	27.88	120.2	115	0.013	0.6	1.89	761.87	37	29.69	28.65	0.77	0.77
CO-171	19	MH-168	27.88	MH-169	25.86	70.8	35	0.013	0.6	2.88	1381.01	20.2	28.65	26.57	0.77	0.71

CO-172	19	MH-169	25.86	O-15	20.7	103.2	20	0.013	0.6	3.49	1826.9	15.2	26.57	21.7	0.71	1

ROAD-20																
Label	Road Name	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (Scaled) (m)	Slope (Calculated) (1/S)	Manning's n	Width(m)	Velocity (m/s)	Capacity (Full Flow) (L/s)	Flow / Capacity (Design) (%)	Elevation Ground (Start) (m)	Elevation Ground (Stop) (m)	Depth (Start)m	Depth (Stop)m
CO-455	20	MH-363	-1.05	MH-469	-0.18	87	-100	0.013	0.6	2.41	1374.34	41.3	1.36	1.38	2.41	1.56
CO-456	20	MH-469	-0.18	MH-470	-0.05	95.8	-711.462	0.013	0.6	1.14	742.12	69.3	1.38	1.33	1.56	1.38
CO-457	20	MH-470	-0.05	MH-471	0.03	82.7	-1000	0.013	0.6	1.01	625.97	83.4	1.33	1.35	1.38	1.32
CO-458	20	MH-471	0.03	MH-472	0.14	105.2	-1000	0.013	0.6	1.02	625.97	85	1.35	1.61	1.32	1.47
CO-459	20	MH-472	0.14	MH-473	0.2	62.5	-1000	0.013	0.6	1.02	625.97	86	1.61	1.55	1.47	1.35
CO-460	20	MH-473	0.2	MH-474	0.25	48.1	-1000	0.013	0.6	1.02	625.97	86.8	1.55	1.39	1.35	1.14
CO-461	20	MH-474	0.25	MH-475	0.3	47.8	-1000	0.013	0.6	1.03	625.97	87.6	1.39	1.61	1.14	1.31
CO-462	20	MH-475	0.3	MH-476	0.32	18.3	-1000	0.013	0.6	0.94	434.6	89.6	1.61	1.61	1.31	1.29
CO-463	20	MH-476	0.32	MH-477	0.34	19.9	-1000	0.013	0.6	0.94	434.6	90	1.61	1.61	1.29	1.27
CO-464	20	MH-477	0.34	MH-478	0.35	15.8	-1000	0.013	0.6	0.94	434.6	90.3	1.61	1.57	1.27	1.22
CO-479	20	MH-478	0.35	MH-492	0.6	244.3	-1000	0.013	0.6	0.83	434.6	95.9	1.57	1.21	1.22	0.61
CO-480	20	MH-492	0.6	MH-479	0.89	170.7	-572.746	0.013	0.6	1.07	341.39	92.4	1.21	1.55	0.61	0.66
CO-477	20	MH-479	0.89	MH-491	0.97	74.2	-1000	0.013	0.6	0.67	258.36	40.7	1.55	1.58	0.66	0.61
CO-348	20	MH-354	-0.11	MH-355	-0.12	15.4	1000	0.013	0.6	0.85	434.6	66.3	1.59	1.59	1.7	1.71
CO-349	20	MH-355	-0.12	O-37	-0.2	75.2	1000	0.013	0.6	0.85	434.6	66.2	1.59	1.5	1.71	1.7

ANNEXURE IV - SUMMARY OF PAVEMENT THICKNESS – DPR 5

Item	Pavement Quality Concrete (PQC)	Dry Lean Concrete (DLC)	Granular Sub-Base (GSB) (as Drainage Layer)	Selected Subgrade (CBR ≥ 8%)
Arya Samaj Road-1	280	100	150	500
Arya Samaj Road-2	250	100	150	500
Bandar Ferry Road	260	100	150	500
Milagress Cross Road	250	100	150	500
Nadiguda Road-1	260	100	150	500
Nadiguda Road-2	260	100	150	500
New Balmatta Road	250	100	150	500