TABLE OF CONTENT

ABBREVIATIONS

AADT	Annual Average Daily Traffic	MOEF	Ministry of Environment and Forests
AC	Asphaltic Concrete	MoRT&H	Ministry of Road Transport & Highways
ADT	Average Daily Traffic	CPWD	Central Public Work Department
BBD	Benkelman Beam Deflection	MSA	Million Standard Axles
BC	Bituminous Concrete	MSL	Mean Sea Level
BM	Bituminous Macadam	NH	National Highway
BOQ	Bill of Quantities	NMT	Non-Motorized Traffic
BOT	Build Operate Transfer	NPV	Net Present Value
BSNL	Bharat Sanchar Nigam Limited	NSDP	Net State Domestic Product
BT	Bituminous Track	NTPC	National Thermal Power Corporation
CBR	California Bearing Ratio	O & M	Operation & Maintenance
CD	Cross Drainage	O-D	Origin Destination
CGWB	Central Ground Water Board	OFC	Optical Fiber Cable
CMSA	Cumulative Million Standard Axles	OMC	Optimum Moisture Content
COI	Corridor of Impact	PCC	Plain Cement Concrete
CRRI	Central Road Research Institute (India)	PCU	Passenger Car Unit
CVPD	Commercial Vehicle Per Day	PIU	Project Implementation Unit
DBFOT	Design, Build, Finance, Operate and Transfer	PPM	Parts per million
DBM	Dense Bituminous Macadam	PPP	Public Private Partnership
DLC	Dry Lean Concrete	PPR	Preliminary Project Report
DTM	Digital Terrain Model	PQ	Pre-Qualification
EA	Environmental Assessment	PQC	Pavement Quality Control
EASL	Equivalent Standard Axle Load	PWD	Public Works Department
EIA	Environment Impact Assessment	QAP	Quality Assurance Plan
EIRR	Economic Internal Rate of Return	QC	Quality Control
FFR	Final Feasibility Report	R & R	Resettlement and Rehabilitation
FIRR	Financial Internal Rate of Return	RAP	Resettlement Action Plans
GAD	General Arrangement Drawing	RCC	Reinforced Cement Concrete
GDP	Gross Domestic Product	RHS	Right Hand Side
GOI	Government of India	RL	Reduced Level
GPS	Global Positioning System	ROB/RUB	Road over Bridge/ Road under Bridge
GSB	Granular Sub-Base	ROW	Right of Way
GTS	Geodetic Triangulation Survey	Rs.	Rupees
Ha	Hectare	SH	State Highway
HDM 4	Highway Design and Maintenance Model (Series 4)	SIA	Social Impact Assessment
HDMQ	Highway Design and Maintenance Model with Congestion Analysis	Sq. Km	Square Kilometer
HFL	High Flood Level	TBM	Temporary Bench Mark
IRC	Indian Road Congress	Temp	Temperature
IRR	Internal Rate of Return	TOR	Terms of Reference
Km	Kilometer	TRL	Transportation Research Laboratory
KMPH	Kilometer Per Hour	UG	Under Ground
LA	Land Acquisition	VDF	Vehicles Damage Factor
LT/HT	Low Tension/High Tension Electric lines	Veh.	Vehicles
m	Meter	VGF	Viability Gap Funding
MDR	Major District Road	WB	World Bank
mm	Millimeter	WBM	Water Bound Macadam
		WMM	Wet Mix Macadam

Executive Summary

EXECUTIVE SUMMARY

Background

Construction of high altitude hill roads to Indo – China Border road under phase – II in the state of Arunachal Pradesh & Sikkim has been entrusted to Central Public Works Department (CPWD) by Ministry of Home Affairs, Department of Border Management, Govt. of India. The work is of National importance having strategic in nature from Border security aspect.

The consultancy work for Preparation of Detailed Project Report has been awarded to M/s L N Malviya Infra Projects Pvt Ltd, Bhopal.

Consultancy Services

Objectives

- The main objective of the consultancy service is to undertake survey/investigation/studies and preparation of a Detailed Project Report for construction of Road in Indo-China Border from **Doginala (E-93^{0}43'20'' & N - 28^{0}24'13'') – Darosi (E-93^{0}38'40''& N-28^{0}33'50'')** in the state of Arunachal Pradesh for length of 35.26 Km and project facilities facilitating assessment of most cost effective/ advantageous/ optimum solution enabling prospective bidders (Contractor/ Agencies for Construction of above stretch of Road) in assessing CPWD's requirement in a clear and unambiguous manner.
- The Detailed Project Report have inter-alia included detailed Road Design, design of flexible pavement, design of bridges, and cross drainage structures, quantities of various items, detailed G.A (General Arrangement) drawing, detailed cost estimates.
- We have ensured detailed project preparation incorporating aspects of value engineering, quality audit and safety audit requirement in design and implementation. We have made effective use of modern technology for carrying out accurate ground surveys and preparation of digital data for design of proposed Border road.
- Provided, CPWD with a sound Engineering Solution scheme with a realistic and firm cost estimate together with a scheme for phased development of the project.
- The project proposal/ Detailed Project Report (DPR) have been prepared with a view to ensure:
  - Establishing the most suitable alignment of road.
  - Minimal adverse impact on environment.

Methodology

For Detailed Project Report (DPR) preparation, following sequences has been followed;

- Detailed reconnaissance
- Complete route survey and planning including
- Procurement of High Resolution Colored Satellite Imageries capable of generation of DTM of 5 m grid and generation of Panoramic/ 3D image.
- Geo – referenced data gathering planning by satellite imagery.
- The ground centre point should be established relative to natural reference points (ITRF) which are

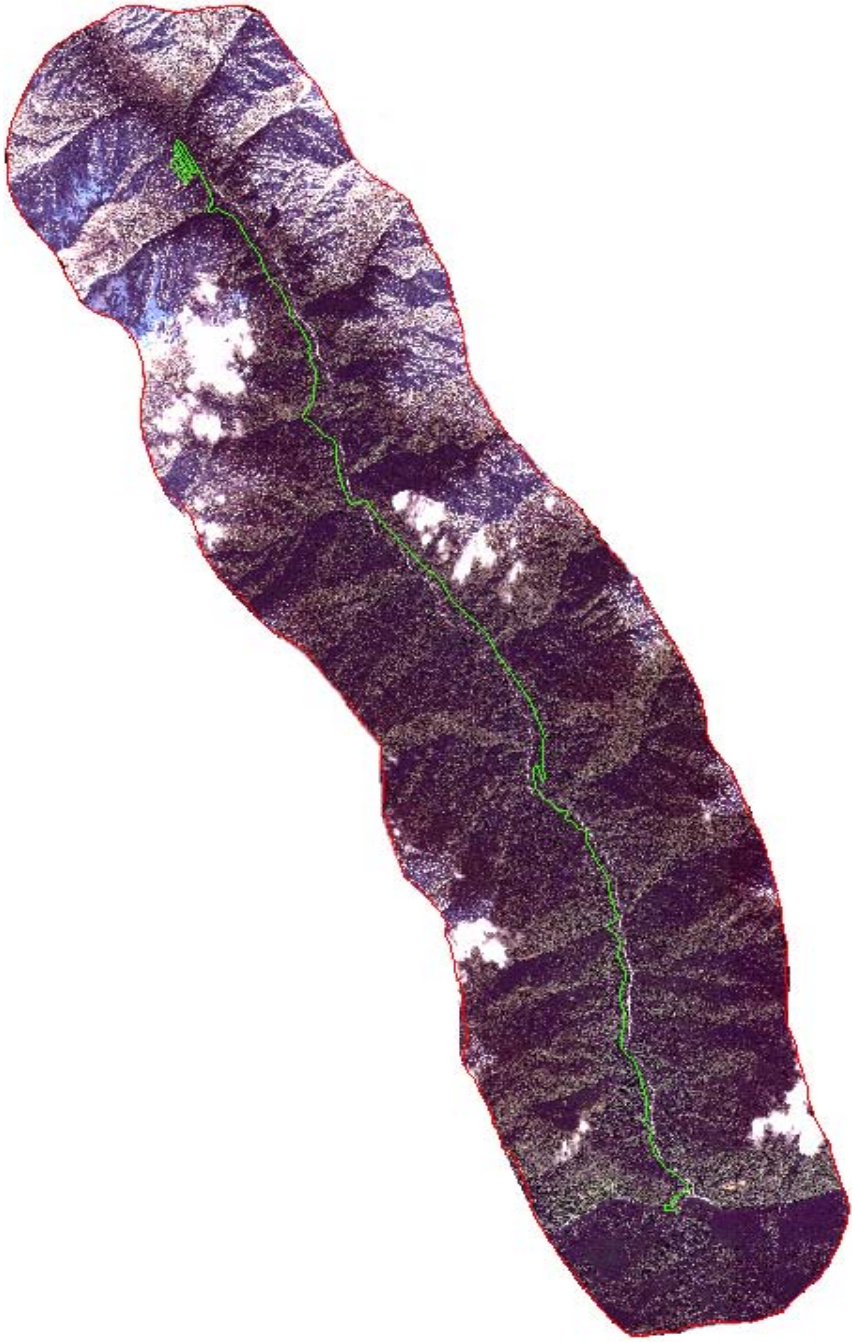
part of natural Geodetic Network and should be collected by using differential GPS. The GCP should be at an interval of 5 km with minimum of 2 control points for each road.

- Applying correction factor to the centre line coordinate of alignment and imagery in Arial triangulation at every 5 km GPS having static accuracy +/- 3mm +0.1 ppm (horizontal) & +/-3.5mm +0.4 ppm (vertical) and Real time kinematic (RTK) +/-8mm + 1ppm (horizontal) & +/-15 mm +1ppm (vertical).
- Detailed satellite imagery interpretation along the alignment of road as per required DTM grid, compiling and processing of data electronically, conversion of data to user editable 2D scaled maps on CAD system that show in detail the route superimposed upon local topography and any other natural or manmade structure and length measurement of proposed route and of other objects may be made by user.
- Ground validation of the coordinate by differential GPS/Total station GPS enable/real time survey equipment with high precision accuracy.
- Identification of most feasible route with currently gathered data.
- Preparing scaled accurate construction route drawing on 1:2500 horizontal scale and 1:250 vertical scale.
- Delivering final construction drawings along with detailed project reports with accuracy and terms and condition complied as per subject tender.
- Detailed design of crust for alignment, after collecting the available data of vehicular traffic sub grade characteristic and strength requirement of Class 9 road.
- Identification of sources of construction materials.
- Detailed geometric design of alignment/ improvement of existing operational track on approved, its X-section, horizontal and vertical alignment and design of structures in alignment like Bridges, Culverts, Causeways etc. Preparation of General Arrangement Drawings (GAD) detailed design of structures and construction drawings and cross drainage structure curves, bends etc. against scope of services. Engineering analysis of sub grade characteristic for roads and embankment design and sub soil investigation. The Freezing/thawing condition and the capillary action have been given specific attention.
- Design of complete drainage system (surface and sub surface) and disposal point for storm water including improvement, if necessary.
- Preparation of detailed project reports, realistic cost estimate, good for construction, realistic rate analysis, detailed bill of quantities, standard contract for execution of civil works, tender documents for construction/up gradation of roads, Bridges/ Bailey bridges and their abutments & pier etc, culverts, causeway, longitudinal drains and other cross drainage structures, site specific geotechnical solution etc.
- MORTH guidelines/hill road manual IRC: SP: 48-1998 has followed.

Vetting By IIT Delhi

DOGINALA-GAU-DAROSI_AOI-17(AP) Pkg-3

(Submission of Final Report to CPWD through IIT Delhi)



Dr. A.K. Keshari
Professor
Department of Civil Engineering
Indian Institute of Technology Delhi
Hauz Khas, New Delhi-110016

Introduction

Consultancy Services for Preparation of Detailed Project Report in High Altitude Hill Roads to Indo China Border under the Phase-II in the State of J&K using Satellite imagery.

Contract has been awarded to *M/s L. N. Malviya Infra Projects Pvt. Ltd.*, *Bhopal,* India

Details of the Road

State	: Arunachal Pradesh
Name	: DOGINALA-GAU-DAROSI_AOI-17(J&K) Pkg-3
Total Length of the road as per remote sensing	: 35.26 km
Total Sqkm Area as per 5km buffer boundary	: 225.688 Sqkm

Detailed Scope of Service

Complete route survey and planning

a) Procurement of High Resolution Colored Satellite Imageries capable of generating of DTM of 5m grid and generation of Panoramic/3Dimage,

b) Geo-referenced data gathering planning by satellite imagery.

c) The Ground Centre point established relative to natural reference points (ITRF) which are part of natural Geodetic Network and should be collected by using differential GPS. The GCP should be at an interval of 5 Km with minimum of 2 control points for each road.

d) Applying correction factor to the centre line coordinates of alignment and imagery in Arial triangulation at every 5 Km intervals using the high precision equipment based on Differential GPS having static accuracy ±3mm+0.1ppm(horizontal) & ±3.5mm+0.4ppm(vertical) and Real Time Kinematic (RTK) ±8mm+1ppm (horizontal) & ±15mm+1ppm (vertical).

e) Detailed satellite imagery interpretation along the alignment of road as per required DTM grid.
Compiling and processing of data electronically, conversion of data to user editable 2D scaled maps showing on CAD system that show in detail the route superimposed upon local topography and any other natural or manmade structure and length measurements of proposed route and of other objects may be made by user.

f) Ground Validation of the coordinates by Differential GPS/ Total Station GPS Enabled/real time survey equipment with high precision accuracy.

g) Preparing scaled accurate construction route drawings on 1:2500 horizontal scales and 1:250 vertical scales.

Objective

- Ground control point survey using DGPS
- Procurement of 0.5 M resolution Satellite imagery from National Remote Sensing Centre (NRSC), Hyderabad, India.
- Development of Geographical Information System(GIS) layers and Digital Elevation Model (DEM) of finalized alignment of Border Roads
- Contours creation at 2.5m interval.
- Orthophoto Generation at 0.5 M GSD

Approach & Methodology

Stage-1

Finalizing the alternative alignment route

Following methodology has been adopted while finalizing the alignment route:

- Corridor marking in Google Pro.
- Available Elevation database such as SRTM\Google elevation has been used for analysis.
- With the help of imagery from Google and Elevation model, best fit alignment has been marked and further fine tuned for fitting and analysis in 0.5m resolution coloured satellite imagery.
- After satisfying horizontal specification requirements of appropriate IRC guidelines, vertical design of the same alignment has been finalized on the basis of IRC codes. Three tentative alignment of the road were marked initially.
- Best suited alignment finalized / suggested. Geometric design has been done for best suited alignment.

Deliverable

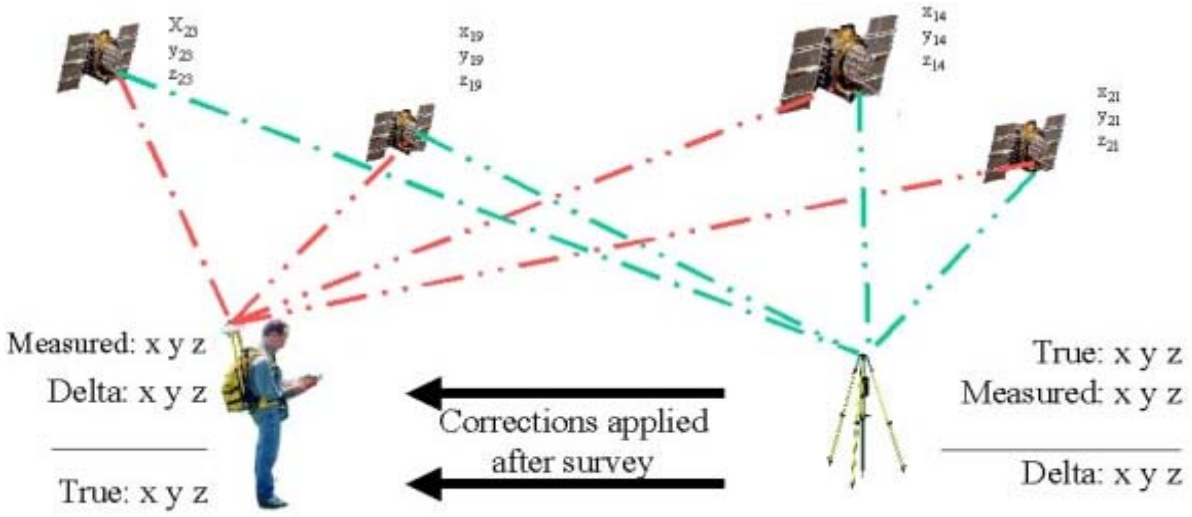
- Plan on Google Pro images with center line and chainages for corridor marking in 5 km width.
- Profile with ground and finished road levels on coloured satellite imagery of 0.5 m resolution.

- No. of bridges
- Description of Best Suited alignment in few lines in Doc format along with screen shots of alignment over the Google imagery as well as elevation profile)
- KML files for all three alignment, (Color coding for Best Suited, 2nd Best, 3rd Option)

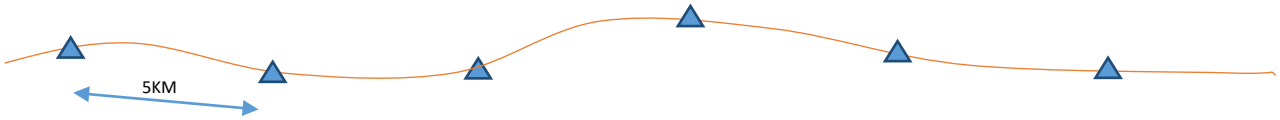
Stage -2

DGPS survey

The Control points planning was done on 0.5 m resolution coloured satellite imagery by indentifying the permanent structure like Bridge location, major culverts or any topographic features which is visible on the imagery. The control points were established on approx. 5 KM distance along the selected alignment using Differential GPS instrument (compatible with L1/L2 & Glonass to achieve "**Sub-meter accuracy**" of the ground control points.



Control Point Survey Pattern along the alignment:



Deliverables DGPS:

Duly networked Ground Control Points in txt, Exl format – XYZ along with its photos, sketches etc.

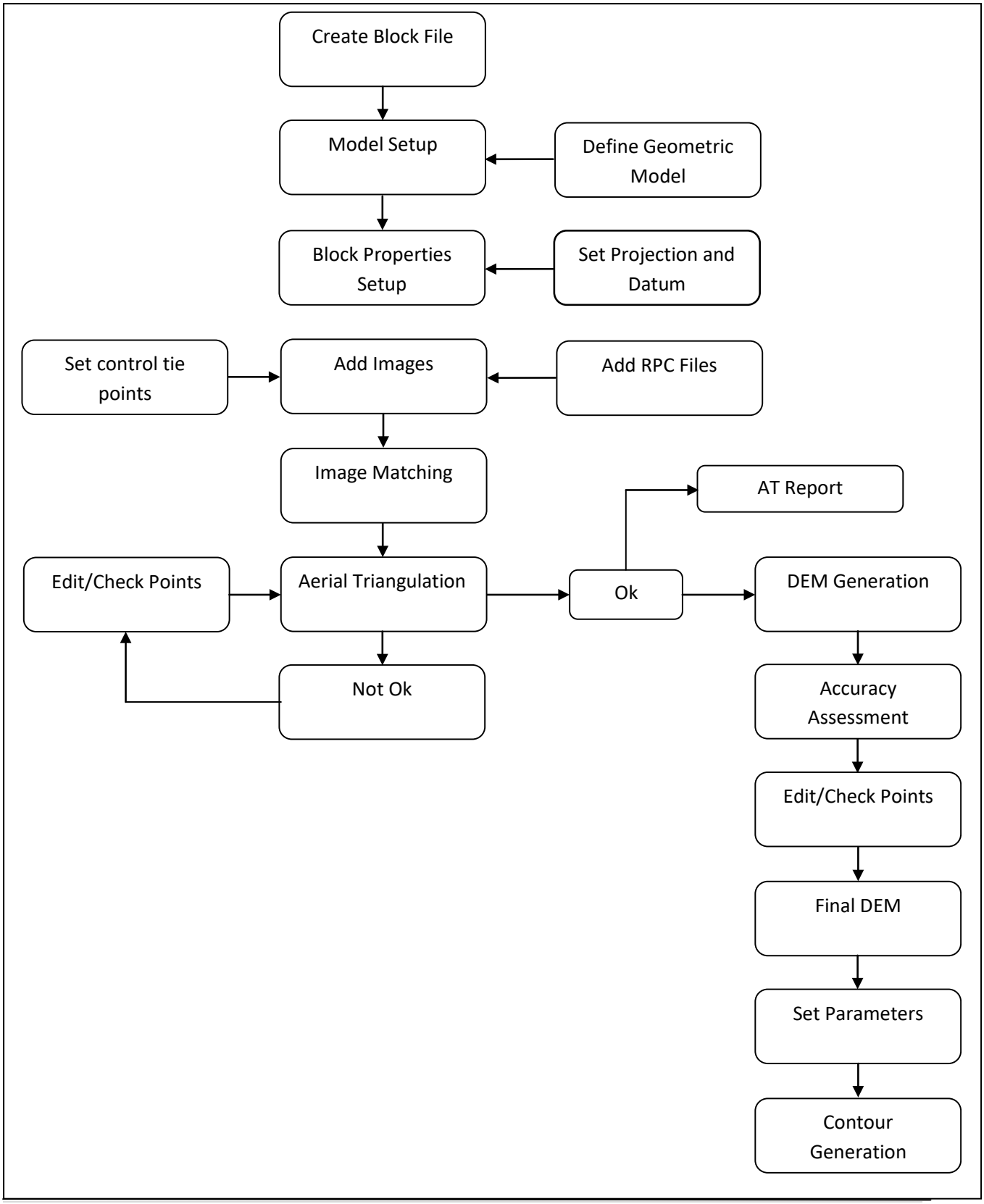
Satge-3

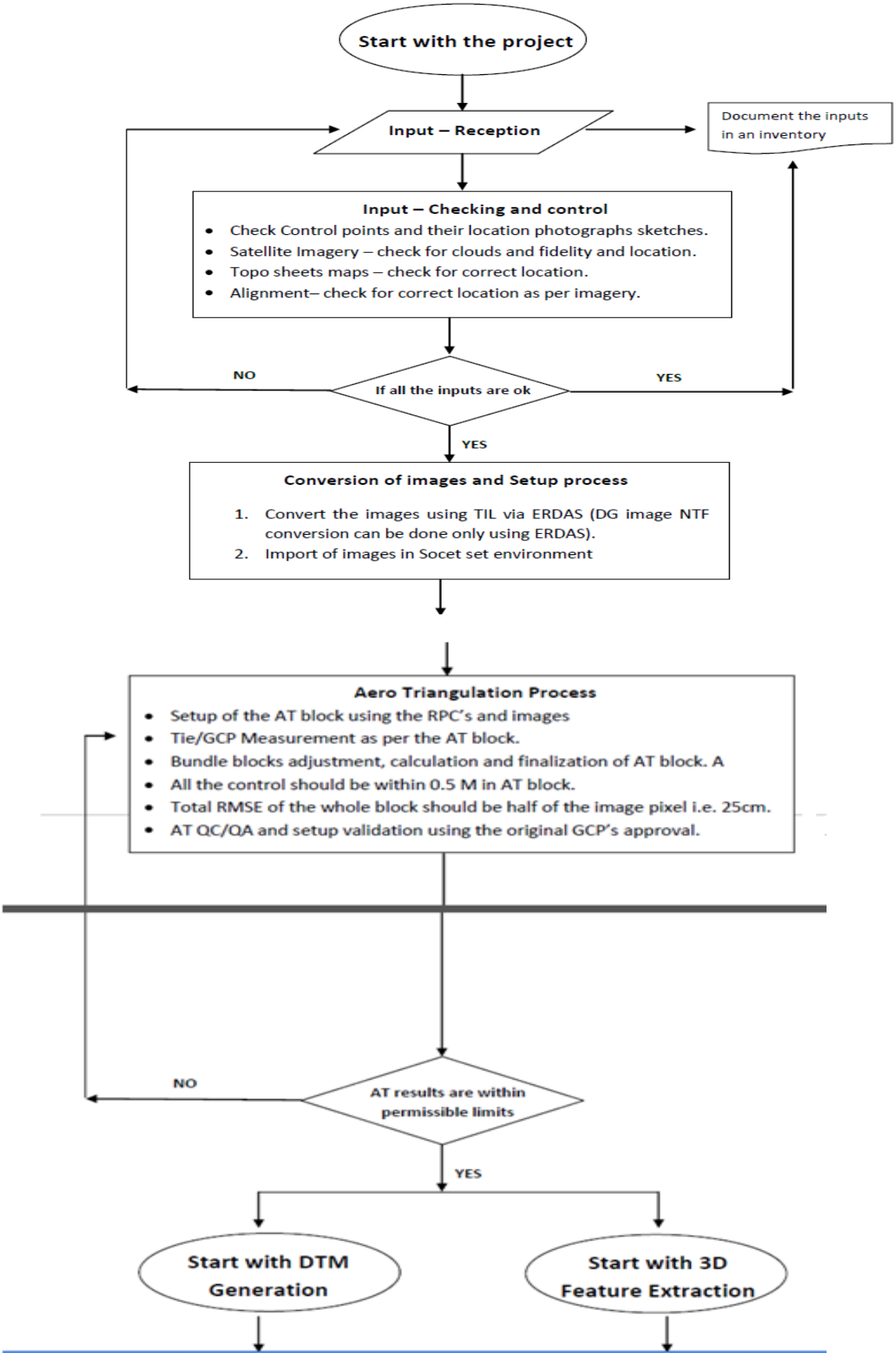
Summary - Satellite data Processing

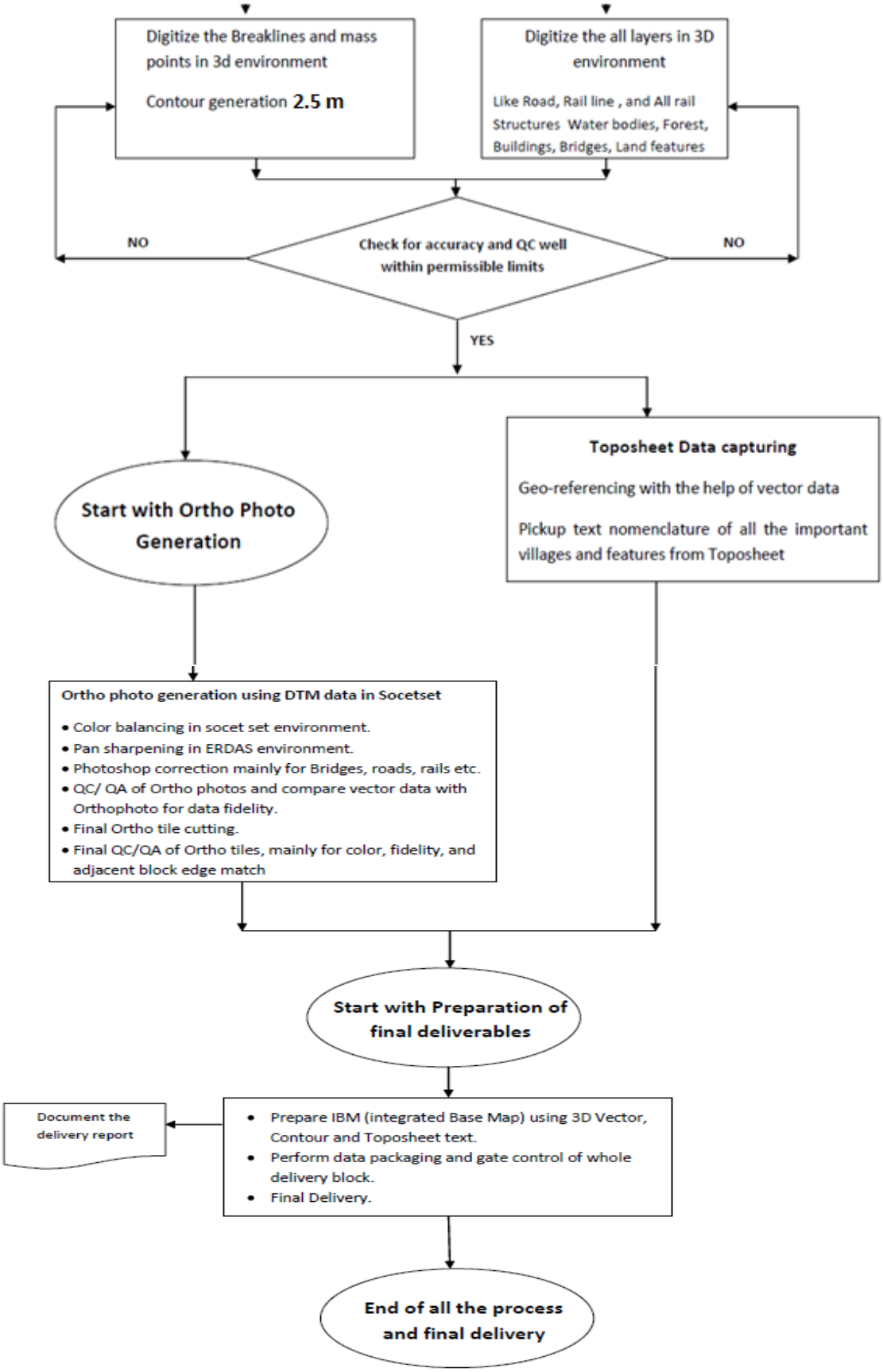
After finalization of the alignment and DGPS Survey, the following steps has been followed to carried out the "Satellite data Processing"

1. **Input Procurement – Reception and control**
   - Ground Control points and their location.
   - Satellite Imagery procurement – check for clouds and fidelity and location.
   - Toposheets maps – check for correct location.
   - Alignment– check for correct location as per imagery.
2. **Conversion of images and Setup process -** Import of images in Socetset environment.
3. **Aero Triangulation Process –**
   a. Tie/GCP Measurement as per the AT block.
   b. Bundle blocks adjustment, calculation and finalization of AT block. A
   c. All the control should be within 0.5 M in AT block.
   d. Total RMSE of the whole block should be half of the image pixel i.e. 25cm.
   e. AT QC/QA and setup validation using the original GCP's approval.
4. **3D vector data creation and DTM generation**
   This activity takes place using 3D stereo workstation. In this activity followings are the major process and factors.
   a. Accuracy for vertical/Elevation/Z data generally DTM and contours is 2 M
   b. Accuracy for Horizontal/Plan/XY data generally 3D vector or Planimmetric data is 1 M
   c. Perform quality control over 3D Vector data and DTM data.
   d. Contour generation at 2.5M interval using DTM.
5. **Ortho photo generation with the help of vector data and DTM data using Socetset.**
   a. Color balancing in socet set environment.
   b. Pan sharpening (Mono and Multispectral merging process) in ERDAS environment.
   c. Photoshop correction mainly for Bridges, roads, rails etc.
   d. QC/ QA of Ortho photos and compare vector data with Orthophoto for data fidelity.
   e. Final Ortho tile cutting.
   f. Final QC/QA of Ortho tiles, mainly for color, fidelity, and adjacent block edge match
6. **Toposheet Data capturing** –
   This includes Geo-referencing with the help of vector data.
   a. Pickup text nomenclature of all the important villages and features from Toposheet.
7. **Finalization and delivery preparation** –
   a. Prepare IBM (integrated Base Map) using 3D Vector, Contour and Toposheet text.
   b. Perform data packaging and gate control of whole delivery block.
   c. Final Delivery.

Brief workflow




Start with the project
Input – Reception
Document the inputs in an inventory
Input – Checking and control
Check Control points and their location photographs sketches.
Satellite Imagery – check for clouds and fidelity and location.
Topo sheets maps – check for correct location.
Alignment– check for correct location as per imagery.
NO
If all the inputs are ok
YES
YES
Conversion of images and Setup process
1. Convert the images using TIL via ERDAS (DG image NTF conversion can be done only using ERDAS).
2. Import of images in Socet set environment
Aero Triangulation Process
Setup of the AT block using the RPC's and images
Tie/GCP Measurement as per the AT block.
Bundle blocks adjustment, calculation and finalization of AT block. A
All the control should be within 0.5 M in AT block.
Total RMSE of the whole block should be half of the image pixel i.e. 25cm.
AT QC/QA and setup validation using the original GCP's approval.
NO
AT results are within permissible limits
YES
Start with DTM Generation
Start with 3D Feature Extraction


Digitize the Breaklines and mass points in 3d environment
Contour generation 2.5 m
Digitize the all layers in 3D environment
Like Road, Rail line , and All rail Structures Water bodies, Forest, Buildings, Bridges, Land features
Check for accuracy and QC well within permissible limits
NO
NO
YES
Start with Ortho Photo Generation
Toposheet Data capturing
Geo-referencing with the help of vector data
Pickup text nomenclature of all the important villages and features from Toposheet
Ortho photo generation using DTM data in Socetset
• Color balancing in socet set environment.
• Pan sharpening in ERDAS environment.
• Photoshop correction mainly for Bridges, roads, rails etc.
• QC/ QA of Ortho photos and compare vector data with Orthophoto for data fidelity.
• Final Ortho tile cutting.
• Final QC/QA of Ortho tiles, mainly for color, fidelity, and adjacent block edge match
Start with Preparation of final deliverables
Document the delivery report
• Prepare IBM (integrated Base Map) using 3D Vector, Contour and Toposheet text.
• Perform data packaging and gate control of whole delivery block.
• Final Delivery.
End of all the process and final delivery

Aero-Triangulation of satellite Imagery:

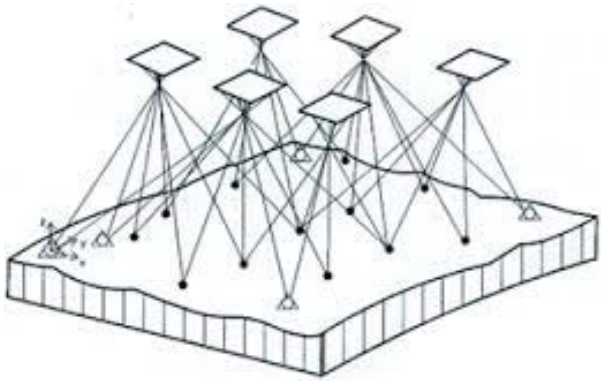
The triangulation process has been conducted on the satellite imagery received from **NATIONAL REMOTE SENSING CENTRE, HYDERABAD** and using ground control points from DGPS survey.

M/s L N MALVIYA INFRA PROJECTS PVT LTD had conducted an exercise of Aerial Triangulation of contiguous densifying and extending Rational Polynomial Coefficient supplied with the Satellite images through computational means. This operation includes measuring and transferring all tie, check, and control points appearing on all photographs manually; and performing a least squares block adjustment. This process ultimately provided the exterior orientation parameters for satellite stereo-pair and three-dimensional co-ordinates for measured object points.

The Aerial Triangulation process had refined the Exterior Orientation parameters (X,Y, Z,) computed through direct geo-referencing for each imagery, to help in achieving the desired accuracy while generating DTM.

Specifications of Block Triangulation

- Projection: UTM
- Spheroid: WGS 84 (World Geodetic System)
- Datum: WGS 84
- Zone: As applicable
- Hemisphere: North



AT Process

1. Reception of 0.5m images from NATIONAL REMOTE SENSING CENTRE and its visual check.
2. Conversion and import of Satellite images in to the Photogrammetry software. (Socetset)
3. Preparation of AT block with provided project input Information.
4. Measurement of tie and Ground control points (GCP's) in the images.
5. Block Bundle adjustment
6. Final quality check

Triangulation Quality Assessment

The Accuracy of the final Integrated based map highly depends on the quality of the DGPS control and triangulation process.

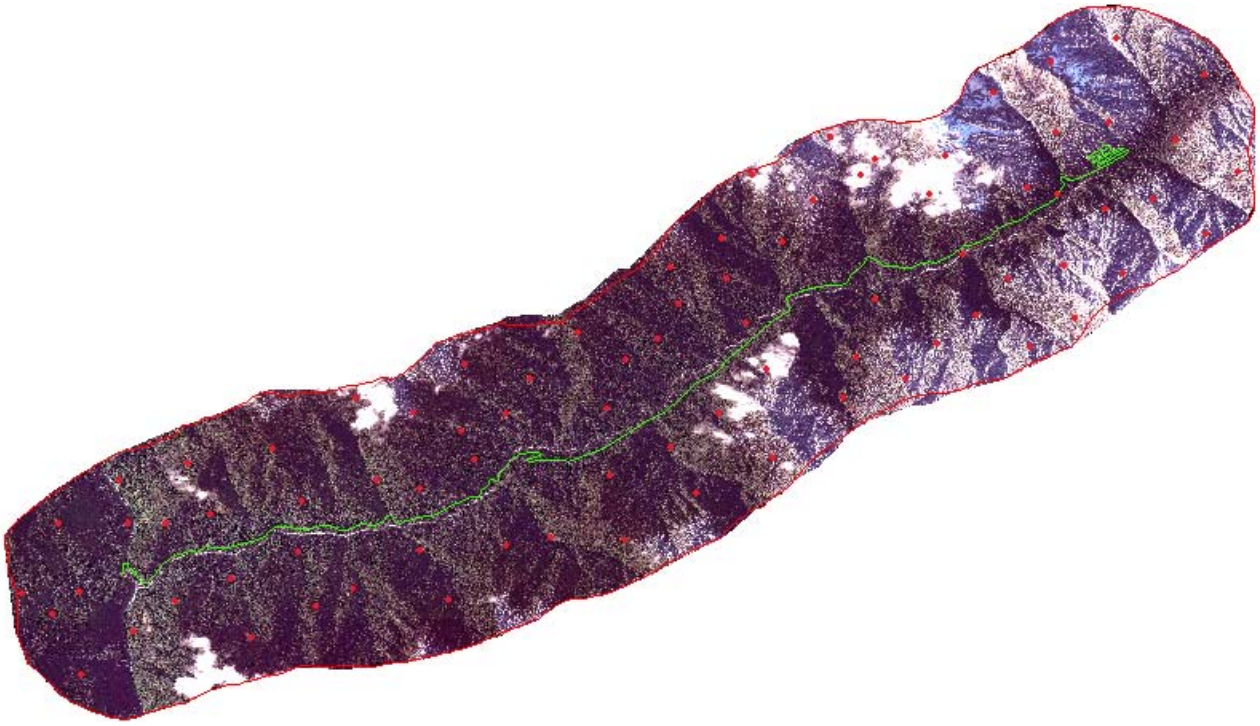
M/s L N MALVIYA INFRA PROJECTS PVT LTD had performed the quality check processes during calculation and after final adjustment using in-house designed checklist. The Checklist is based on the national and international standards and procedures related to various aspect such as GCP specification, RMSE, Tie Points parameter, relative accuracy, parallax etc.

QC has been done after final adjustment for the following factors

- Check for RMSE required for GCP's.
- Check for the parallax in the stereo pairs.
- Datum difference in between stereo pairs
- Check for datum difference in between adjacent blocks within the area of scope
- Check for GCP's on stereo pair in the stereo for its correct location as per sketches.

Triangulation Deliverables

- Block Triangulation Report
- Support files for the stereo pairs
- List of all adjusted coordinates for all ground control, pass points and tie points.
- List of differences at ground scale between surveyed and adjusted coordinate values for ~control points.
- List of differences at ground scale between measured and adjusted tie photogrammetric points.



AT – Quality Control Reports

The AT has been checked according to the National Standard for Spatial Data Accuracy (NSSDA) the detailed report is as follows:

GSD	0.5m													
GCP ID	Ground Control Points			Stereo Observed Test Points			Difference			RMSE (diff in)2				Remarks
	X	Y	Z	X	Y	Z	Dx	Dy	Dz	(diff in x) ^{2}	(diff in y) ^{2}	(diff in z)^2	(diff in x)^2 + (diff in y)2	
1GPS1	570933.542	3142222.965	715.966	570933.5092	3142222.818	716.041	0.03	0.15	-0.08	0.00	0.02	0.01	0.02	Full Control
2GPS1A	570925.138	3142188.356	717.392	570925.2517	3142188.177	717.7674	-0.11	0.18	-0.38	0.01	0.03	0.14	0.05	Full Control
3GPS2	570388.746	3144054.25	851.762	570389.1856	3144054.152	851.6118	-0.44	0.10	0.15	0.00	0.00	0.02	0.00	Vertical Control
4GPS2A	569961.5	3147230.317	1180.138	569960.9465	3147230.595	1179.762	0.55	-0.28	0.38	0.00	0.00	0.14	0.00	Vertical Control
5GPS3	568532.784	3149867.314	1399.772	568532.8977	3149867.135	1400.372	-0.11	0.18	-0.60	0.00	0.00	0.36	0.00	Vertical Control
6GPS4	565930.306	3153744.417	1761.762	565930.5335	3153744.058	1761.536	-0.23	0.36	0.23	0.00	0.00	0.05	0.00	Vertical Control
8GPS4A	565937.919	3153735.731	1761.978	565938.3456	3153735.605	1762.34	-0.43	0.13	-0.36	0.00	0.00	0.13	0.00	Vertical Control
9GPS5	564819.45	3157962.623	1934.634	564819.9551	3157962.818	1934.258	-0.51	-0.19	0.38	0.26	0.04	0.14	0.29	Full Control
10GPS5A	564815.972	3157940.41	1933.549	564816.2978	3157940.491	1933.624	-0.33	-0.08	-0.08	0.11	0.01	0.01	0.11	Full Control
											sum	1.00	0.47	
											average	0.111067467	0.118351	
											RMSE	0.33326786	0.344021802	
											NSSDA	0.653205006	0.595432934	

AT Results

Permissible accuracy RMSE from the AT: XY = 1m

Z = 2m

Achieved RMSE: XY = 0.34m

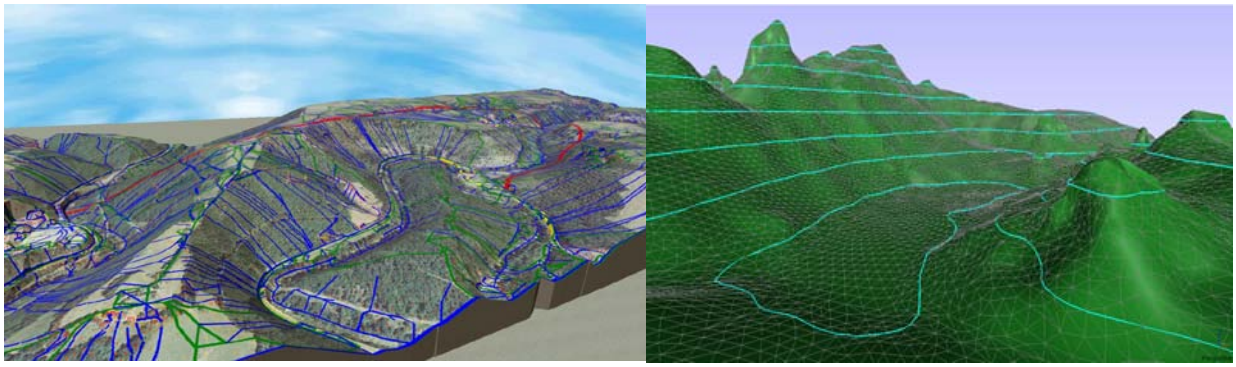
Z = 0.33m

NSSDA Horizontal Accuracy at 95% Confidence Level = 0.59m

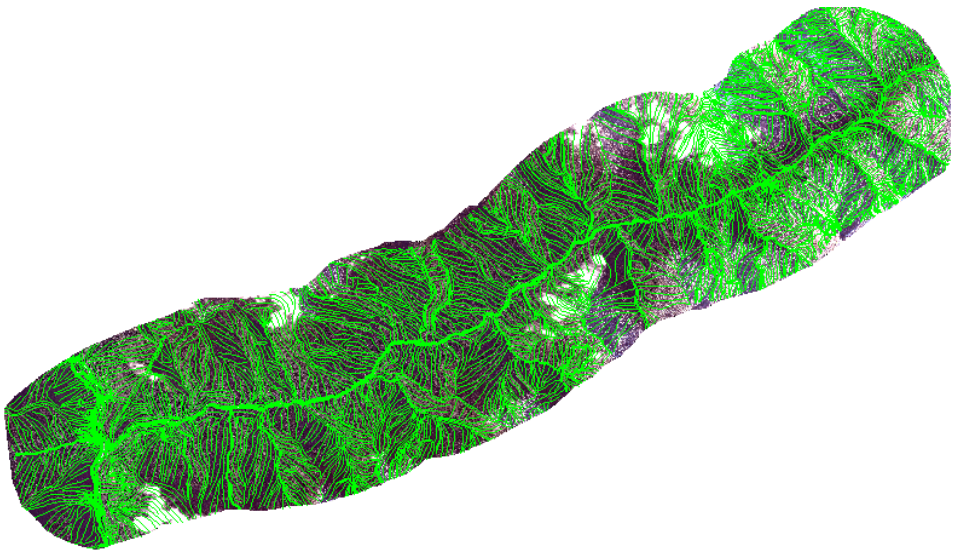
NSSDA Vertical Accuracy at 95% Confidence Level = 0.65m

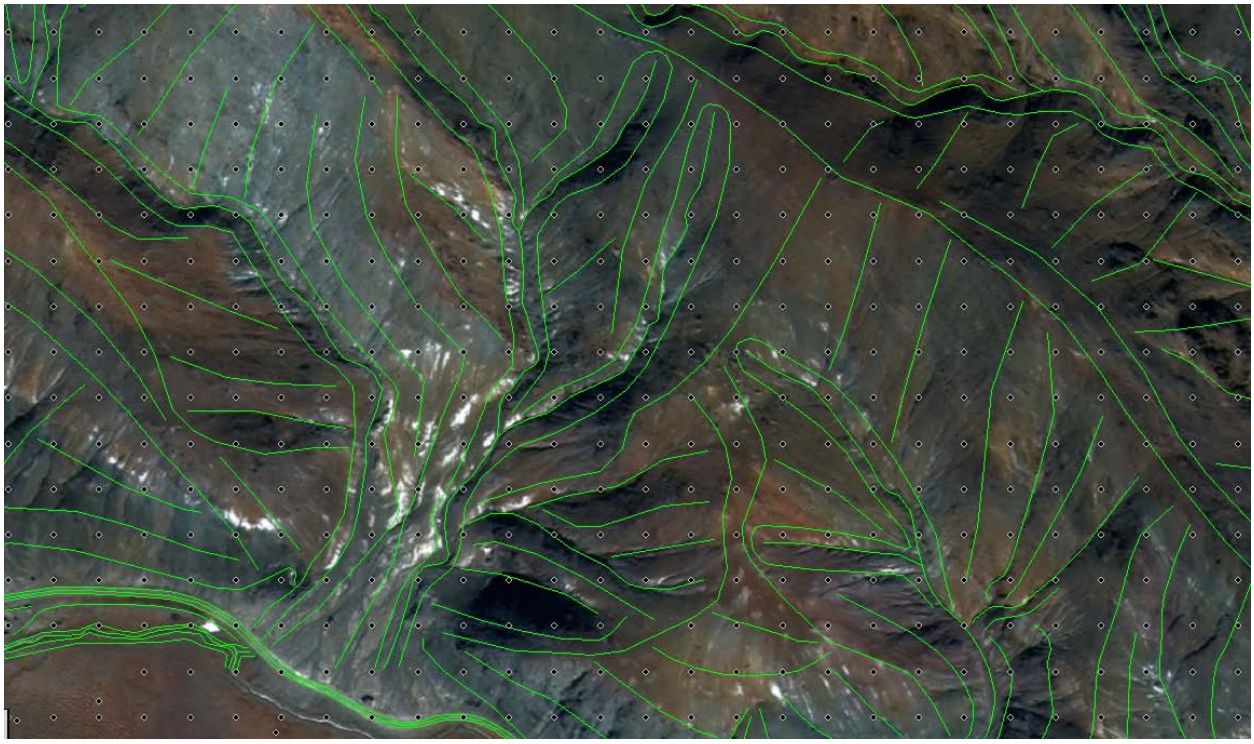
Digital Terrain Model (DTM) \ DEM Generation

Based on the final triangulation result the stereo satellite has been setup in the Photogrammetry software (Socetset) and a hybrid approach were adopted including the Auto generation of DTM points and manual inspection and editing of the elevation points in stereo Photogrammetry software to eliminate points captured over trees, buildings etc. ***ensuring that the DTM were totally at ground level.*** Various ground features will be also captured wherever elevation change present on the ground to prepare the accurate DTM. The 3D breakline were captured on the Transportation features, Hydrography/Hydrological Features, ground level Structures, vertical drops etc for the creation of accurate DTM. Socet-set Photogrammetry software from BAE system has been used for the triangulation and DTM generation.

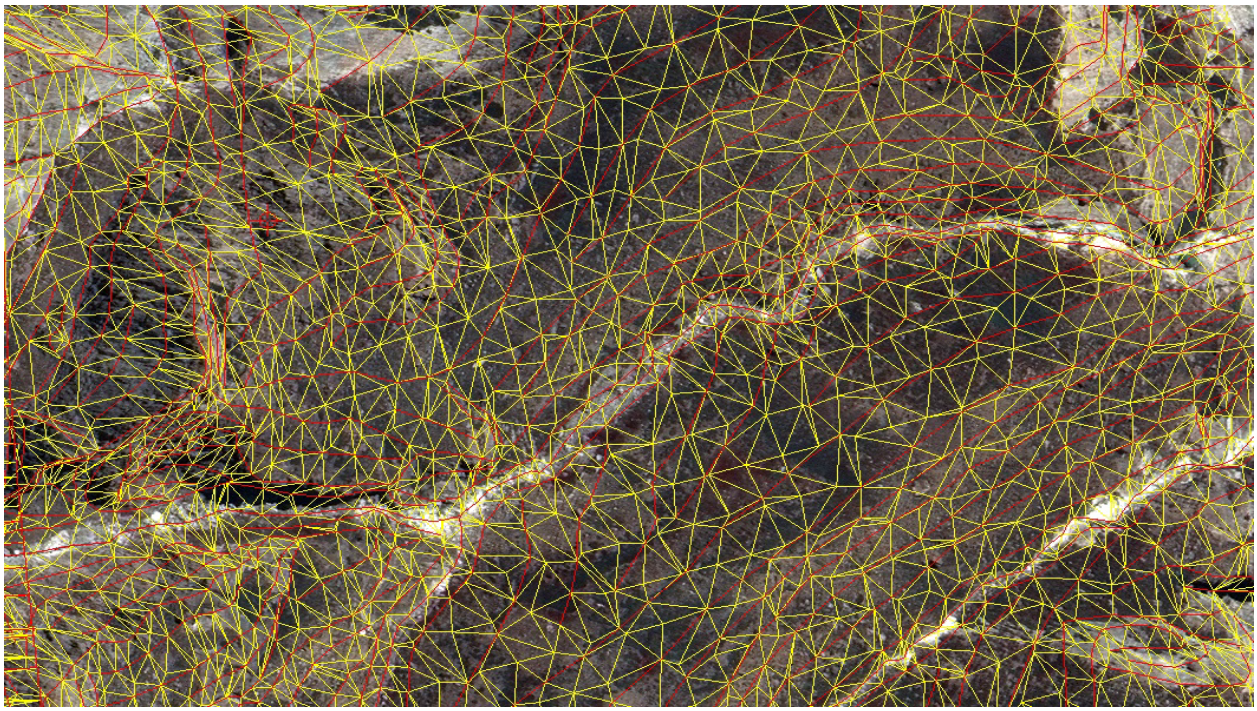


Preparation of DTM/DEM





Compilation of Breaklines (A line portrays the sudden changes in the elevation) and Mass points using Stereo images



TIN Triangulated Irregular Network - Mash showing the faces of terrain

Preparation of DEM

DEM – Digital Elevation Model is an array of spot heights at a certain interval, in the project the 5m Grid is desired.

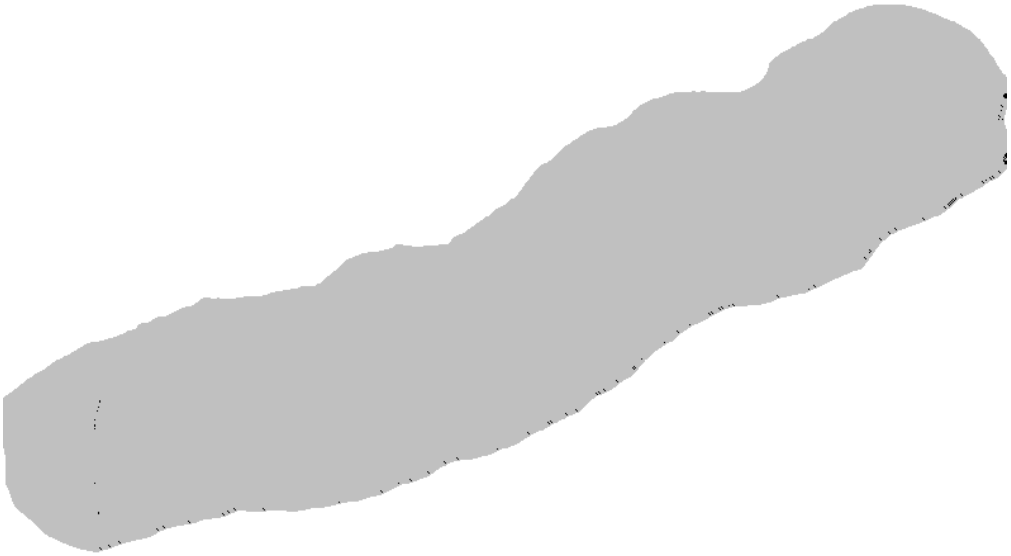


Figure shows the 5m grid points (an overview for the whole area of interest)

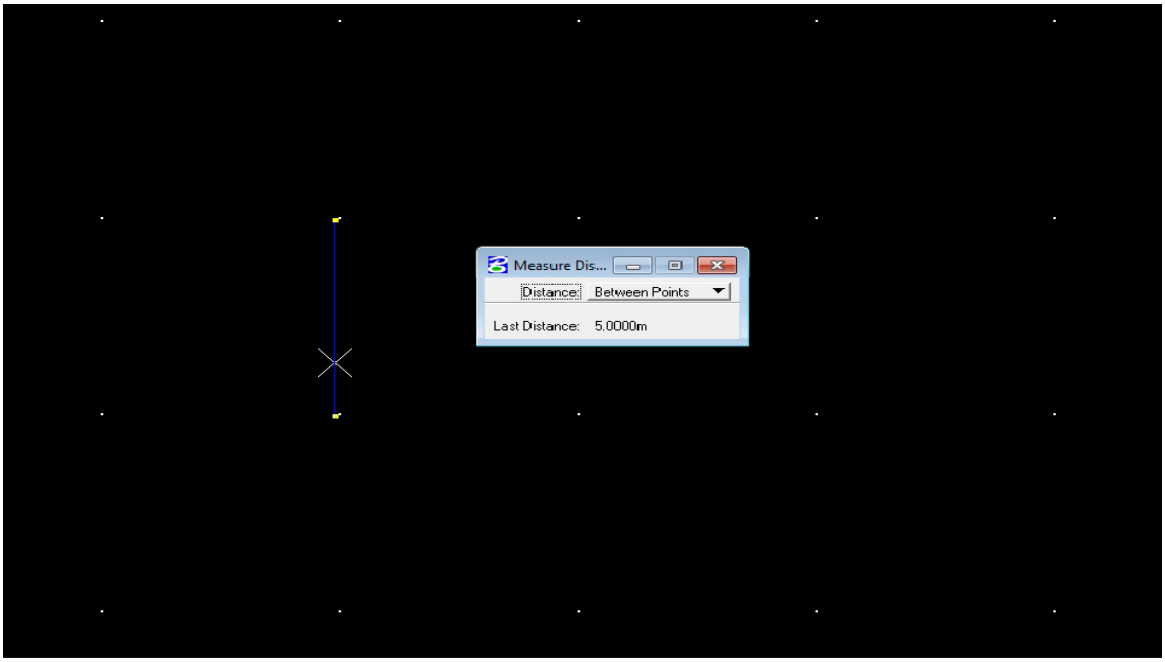


Figure shows the 5m grid points in details.

Generation of DEM in Geo tiff format

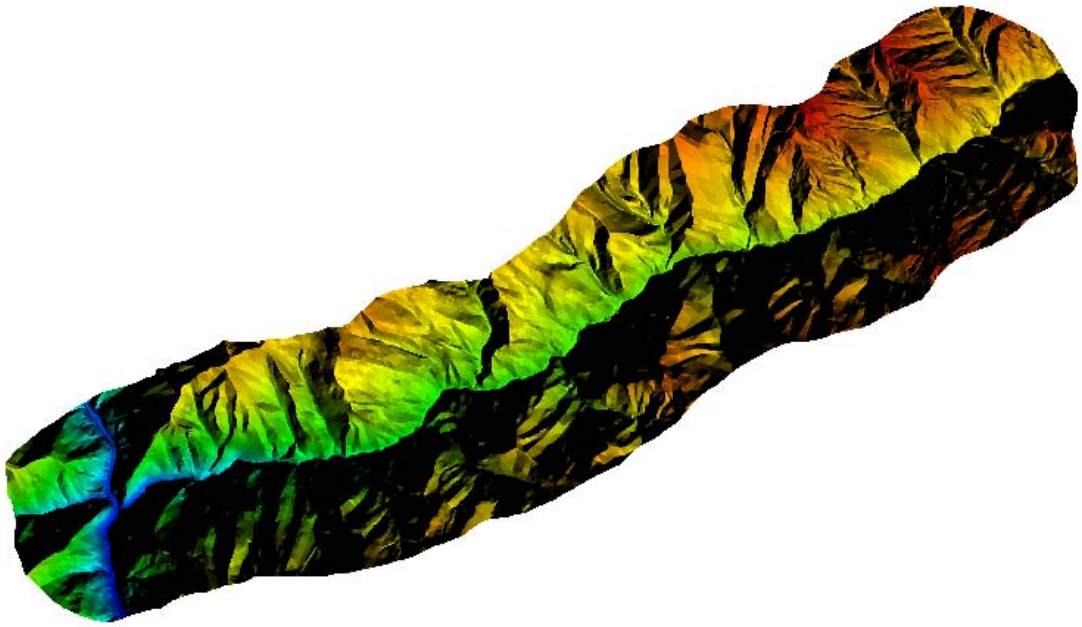


Figure shows the 5m grid DEM a relief view (an overview for the whole area of interest)

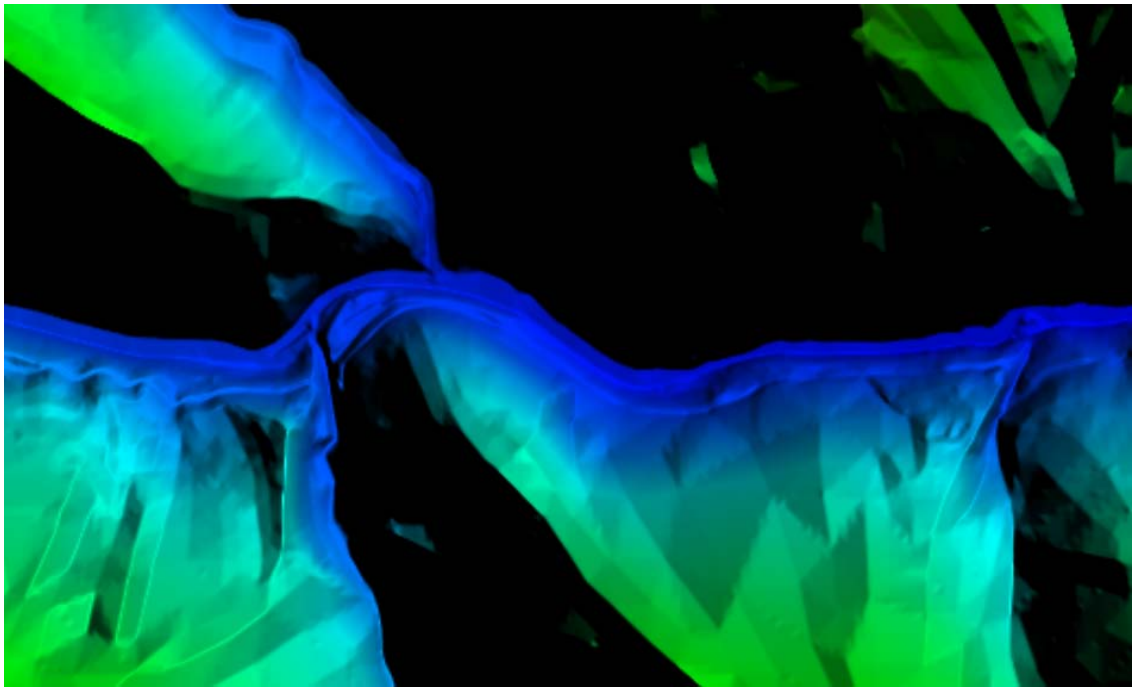


Figure shows the DEM in relief view for a part of a river

PLEASE SEE THE BIG SIZE SHEET IN THE APPENDIX -1 (DEM- A RELIEF VIEW)

Quality Control of DTM and Assurance

- Manual and tool based checks will be performed to ensure accuracy of DTM as per Specification.
- Quality statistics report in comparison to Check and GCP available
- Manual check for Accuracy
- Edge matching,

Generation of Contours

The Contours has been generated at 2.5 M interval from the final DTM. Smooth contours generated are compatible in CAD environment. Every 5th Contours were marked as Major Contour and shown thicker than basic contour. All Major Contour have the value text at every 5 KM in separate layer.

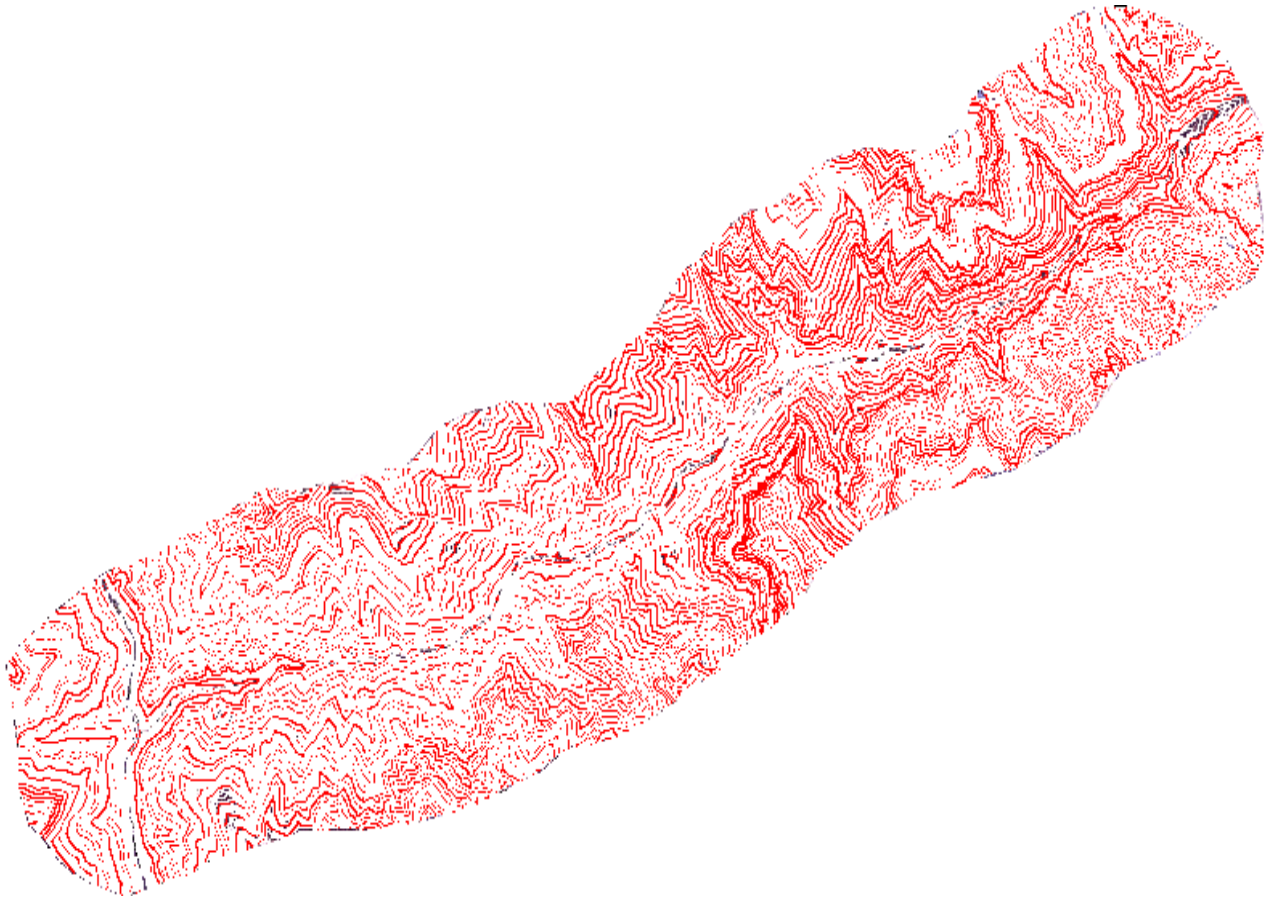


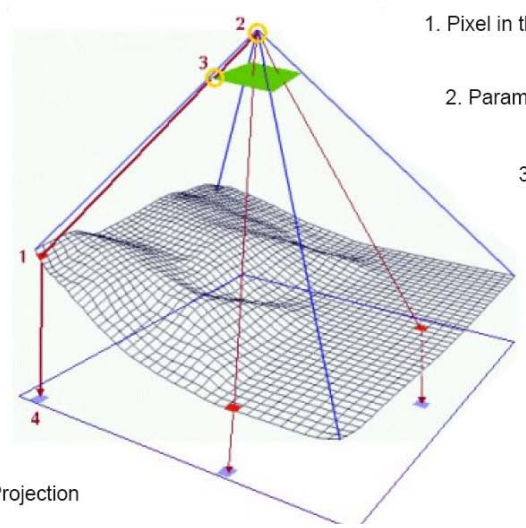
Figure shows an overview of the Contours

PLEASE SEE THE BIG SIZE SHEET IN THE APPENDIX -2 (CONTOURS VIEW)

Generation of Orthophoto

The topographical variations in the surface of the earth and the tilt of satellite sensor affect the distance with which features on the satellite image are displayed. The more topographically diverse the landscape, the more distortion inherent in the image. The "Orthorectification" is a process of geometrical correction of satellite images.

Orthorectification process of remote sensed Image data



1. Pixel in the DEM (Height)
2. Parameters in the Exterior Orientation
3. In the image, a Brightness Value is determined based on the resampling of surrounding pixels
4. Height, Exterior Orientation information and Brightness Value used to calculate equivalent location in the orthoimage

Orthographic Projection

Ortho-rectification of the satellite imagery has been done using the various data like AT, DTM, Control points, projection and registration parameters with following processes.

- Individual scene Ortho-rectification using the triangulated satellite imageries and DTM as per the defined Ground Sample Distance of 50cm
- Verify the geometric accuracy of the Ortho using the available control points.
- Seam line/cutline generation. Edit the seam lines ensuring that seem line does not cross important cultural features.
- Selection the seam line along roads, rivers, streams.
- Perform Mosaicing and automatic global tone balancing.
- Review of tone balance in the mosaic
- Cutting the overall Mosaic in tile based on the file size
- Accuracy of the Ortho Image must be +/- 50cm

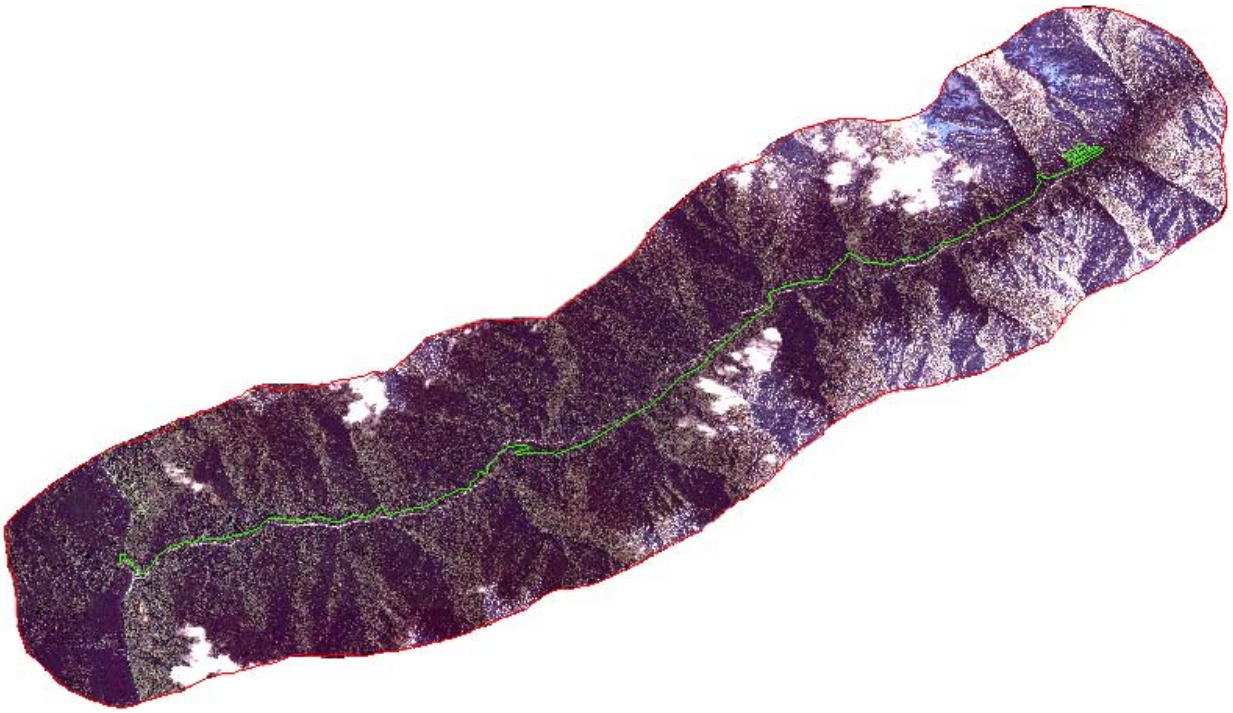


Figure shows an overview of the 50cm GSD Orthophoto

Quality Assurance /Quality Control (Orthophoto)

During QC of ortho mosaic, the following factors were used to ascertain the quality of Orthos

- Check for image completeness
- Check for any bridge/building distortion & deformation
- Critically examine features such as buildings for Orthogonality
- Examine critically the features along the seam line; carry out tone balancing, where necessary.
- Confirm the correct pixel size of Ortho-image
- Measure accuracy of ortho-image by using check points and control points
- Check header information as per specification
- Check for positional accuracy with the help of control points

Ortho Deliverables:

- Ortho mosaic tiles
- Quality report with Screen Shots

Base Map Preparation

Feature extraction of base map features from 50cm Satellite imagery 5km wide corridor. The features such as Road, Railway, river, streams, vegetation, forest, pond/lake, urban area etc has been delineated. The extraction of information/details/features from Survey of India toposheets/Public domain data in a corridor width of 5 Km had also been done.

The layers captured in the integrated 3D map are followings

- River.
- Drainages
- Lakes and Ponds with center points (Standing Water Bodies)
- Buildings and Height points
- Culverts
- Bridges
- Retaining Walls
- Structures.
- Open areas.
- Agriculture Lands
- Privates Lands
- Spot elevations
- Any other miscellaneous feature
- Paved Roads and Center lines.
- Unpaved Roads and Center lines

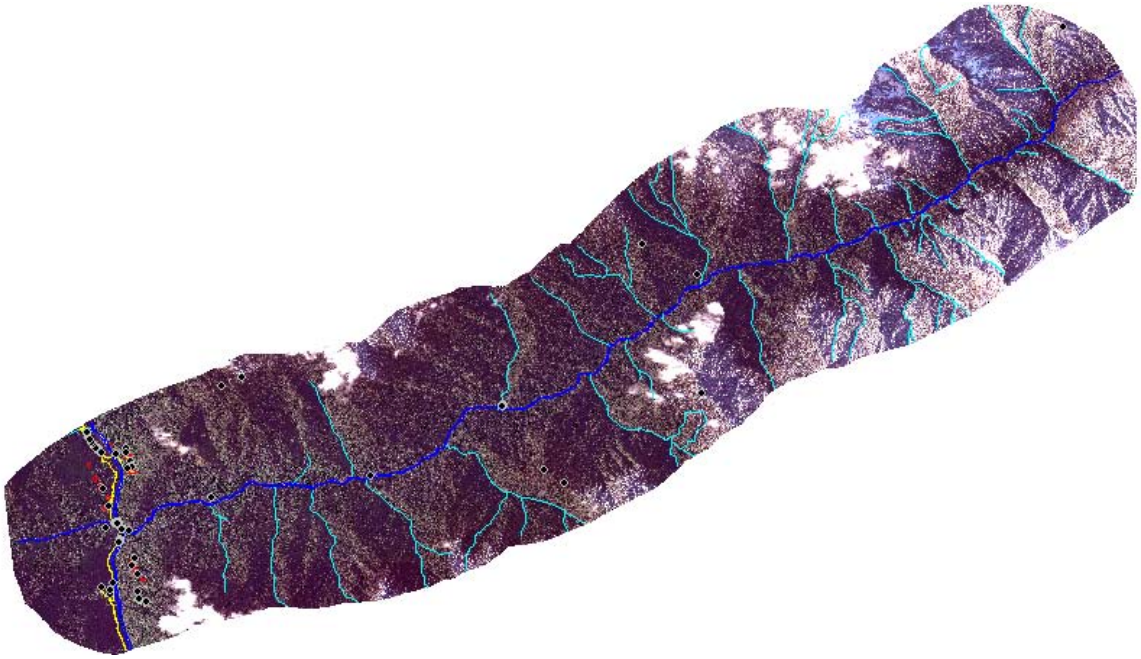


Figure shows plan 3D features over the Orthophoto an overview

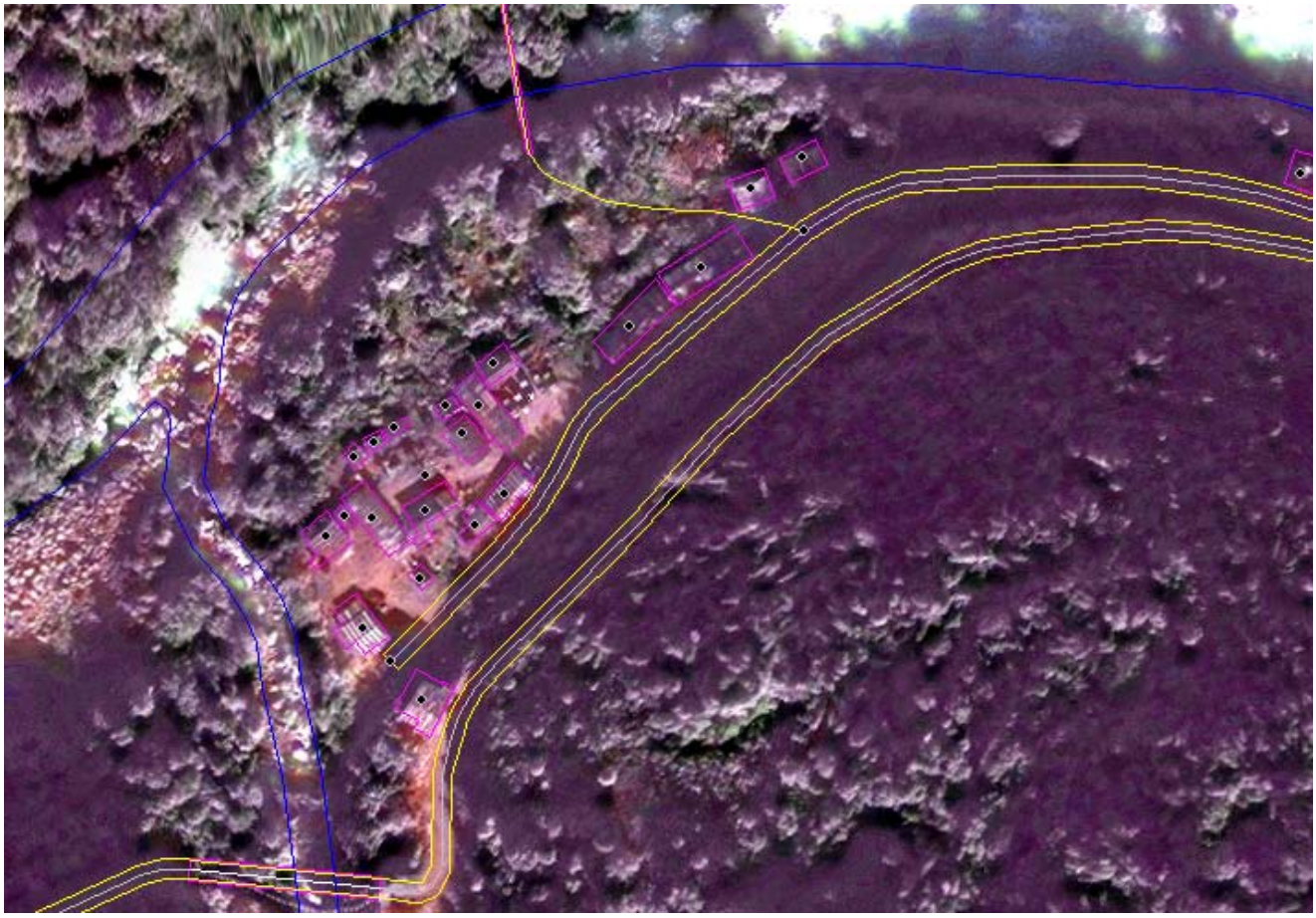


Figure shows plan 3D features – part of a 3d features over the Orthophoto

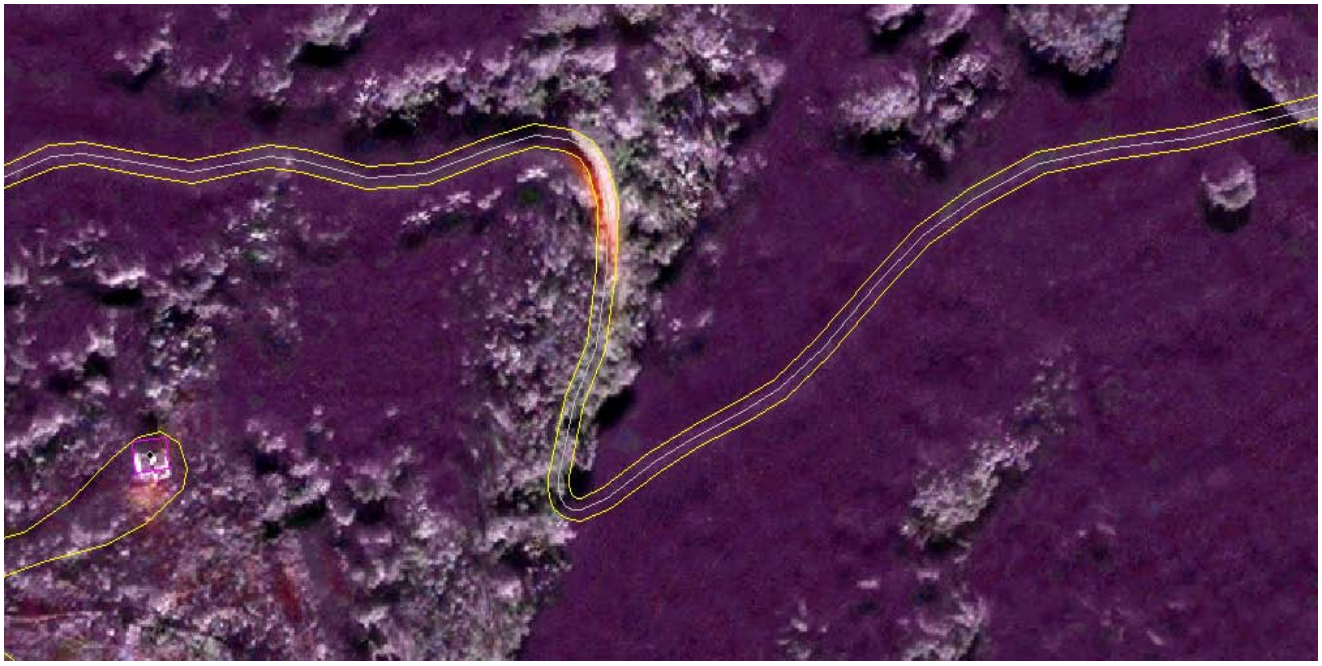


Figure shows plan 3D features – part of road over the Orthophoto

Quality Assurance /Quality Control

The 3D data has undergone through various quality checks before delivery. Some of them are as follows

- Crossing,
- Duplicates,
- River Downhill,
- Polygons Under and over shoot
- Lake and pond same height
- Building and Height points are same

FOR THE QC - CHECK LIST HAS BEEN FOLLOWED PLEASE SEE THE APPENDIX – 3

Deliverable

- DTM derived from Stereo pairs of Satellite Imagery in TIFF/GEOTIFF/ASCII format as files of manageable size along the alignment.
- DEM at 5 M GRID within the 5KM along the Alignment in ASCII/GEOTIFF format
- Ortho-rectified images (50cm GSD) in TIFF/GEOTIFF format
- Contours (2.5m) in AutoCAD environment as files of manageable size.
- Integrated Base Map in CAD format

Integral role of DEM and Integrated Base Map in Finalization of Road Design and DPR Preparation

Considering the Remote sensing data as an input for design of alignment, the further processes of designing the alignment is as follows:

- Identification of start - end point of the alignment and finding the best possible route to join both the points through longitudinal contours. In case, the continuous contour is not available or the contours are in cross shape, we are providing the turning / zigs at the locations from where we may cross the contours without disturbing the gradient by having a longer length. By this method, we are preparing the Horizontal Alignment with the help of Bentley MX Road software.

- After that we are superimposing the horizontal alignment onto the DEM as well as Ortho image to find out any discrepancy such as water body, houses, villages, Army camps etc. to avoid the rehabilitation issue.
- Once the alignment is finalized, we are preparing the vertical profile based on contours and levels of the terrain by keeping the gradient as specified in the IRC code provisions. In case, there is any excess cutting, we are shifting the alignment sufficiently away from that point in order to reduce the cutting quantity.

- After finalization of Horizontal and vertical profile, we are having the plan again on Ortho / DEM to identify the water bodies crossing the alignments in order to provide cross drainage works to cater for the runoff.

After the following checks, the alignment is ready to deliver to the Client:

- The plan should not cross any habitation area / army camps / major vegetation.
- The water bodies on the alignment must be addressed through proper cross drainage works
- The profile must be within the gradients limits specified in IRC SP 48 - 1998.
- There should not be any excess cutting or any shorter route available throughout the alignment.

Project Details

Sl. No	Item	Details	
1	Name of Project	Consultancy Services for preparation of DPR and detailed design of Roads and Bridges etc. for construction of High Altitude Hill Roads to Indo-China Border under Phase-II in the State of Arunachal Pradesh using satellite imagery	
2	Name of Road	DOGINALA-GAU-DAROSI	
3	Length of Road	35.26 km	
4	No. & type of Structure	Slab Culvert	107 No.
		Hume Pipe Culvert	35 No.

Design Parameters as per IRC SP 48 - 1998

Sl. No.	Item	Mountainous/Steep Terrain
1	Design speed (kmph)	30 Kmph, As per IRC:SP:48-1998, sub clause 6.3.1
2	Right of Way	18.00 m
3	Width of carriageway (m)	3.75 m
4	Paved shoulders	-
5	shoulders	2 x 1.25 m
6	**Camber/cross fall**	
(i)	Carriageway & paved shoulders	2.0%
(ii)	Earthen shoulders	2.5%
7	Maximum super elevation	7%
8	Minimum Radii of horizontal curves (m)	30m Ruling /20m Absolute min.
9	Minimum length of vertical curves (m)	15 m
11	Drains	As per Design
12	Sight Distance	As per IRC:SP:23
13	**Gradient**	
(i)	Ruling Gradient	5%
(ii)	Limiting Gradient	6%
(iii)	Exceptional Gradient	7%

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Event Log/Comments from IIT Delhi

During the meetings and presentations with IIT Delhi, some points were raised by them given as follows those points have been incorporated in the data and reports.

Meeting date 3/15/2016 5:00 PM / *Meeting location* IIT Delhi

Attended by:

IIT Delhi- : Prof. Ashok Kumar Keshari and Team

CPWD-: Mr. A. K. Arora, Executive Engineer.

L N MALVIYA INFRA PROJECTS-: Mr. Saurabh, Mr. Rahul Jain, Mr. Raj Kumar

DISCUSSION AND ACTIONS HELD IN THE MEETING

1. **Technology discussed** - We had discussion about the Photogrammetry & GIS Technology to complete the Border Roads project. IIT – Delhi raised some questions

    1) How the GCPs have been taken
    2) Which satellite imagery have been used
    3) What software has been used to process the imagery
    4) What would be the final products deliverables after data processing
    5) How the quality and accuracy of the final data has been ensured
    6) What would be the quality checks and its reporting structure

2. Prof Ashok Kumar Keshari from IIT Delhi asked about Photogrammetry process flow, Mr. Rahul Jain from **M/s L N MALVIYA INFRA PROJECTS PVT LTD** (Matrix Geo) gave a presentation for the same to answer all the queries about the processes and the questions as given above about the technology.

3. **M/s L N MALVIYA INFRA PROJECTS PVT LTD** has provided a Quality check procedure report for the project to IIT Delhi as desired.

4. **IIT- Delhi** asked about Orthophoto corrections of the bridge and asked to submit a sample of processed imagery in **IIT Delhi.**

Meeting date *4/25/2016 4:00 PM*| Meeting location *IIT Delhi*

Attended by:

IIT Delhi- : Prof. Ashok Kumar Keshari

M/s L N MALVIYA INFRA PROJECTS PVT LTD -: Mr. Mukesh Soni, Mr. Rahul Jain, Mr. Raj Kumar

DISCUSSION AND ACTIONS HELD IN THE MEETING

1. M/s L N MALVIYA INFRA PROJECTS PVT LTD submitted the desired documents and data for this project to IIT Delhi.

2. M/s L N MALVIYA INFRA PROJECTS PVT LTD submitted the Ortho photo Example to IIT Delhi that was sought in earlier meeting.

3. M/s L N MALVIYA INFRA PROJECTS PVT LTD submitted the desired AT Reports (NSSDA reports) to IIT Delhi with GCP Observation report.

4. M/s L N MALVIYA INFRA PROJECTS PVT LTD submitted the desired the output deliverables like DEM, DTM, Ortho and Contours file to IIT Delhi.

5. M/s L N MALVIYA INFRA PROJECTS PVT LTD submitted the all roads along with final data with Quality report of related Roads to IIT Delhi.

Conclusion

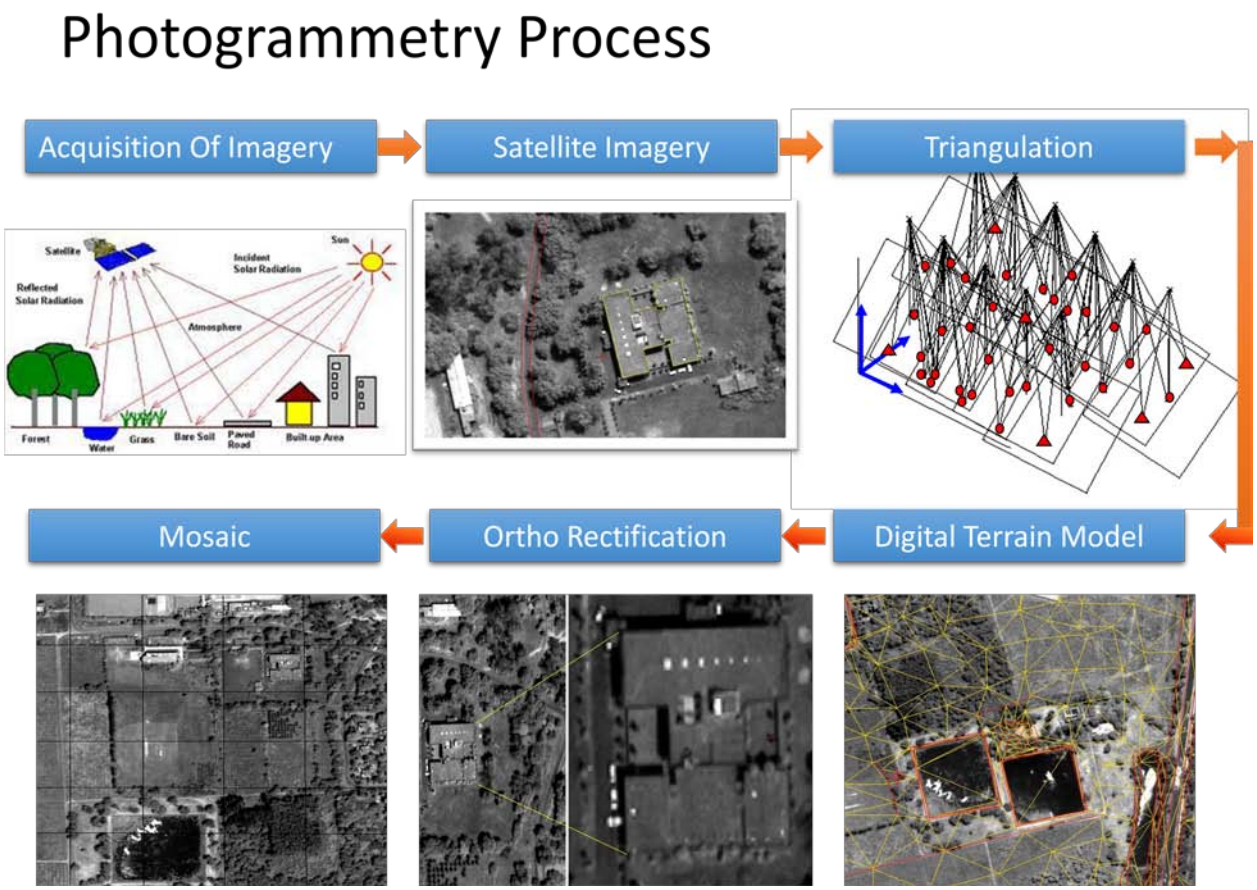
The remote sensing technology (Stereo Photogrammetric) has been proven a fastest method of carrying out the topographical survey within the hilly terrain areas, thus considering the same advantages the RS technology has been used in CPWD Road DPR projects. Even though the areas are of very complex geography and terrain, the RS technology was able to provide fast and reliable DEM – Digital Elevation Model, Topographical features and base data to prepare such complex geography road DPR projects.

In the project, 0.5 m Very High resolution multispectral satellite imagery (World View - 2) from Digital Globe – USA has been used. This imagery was procured through National Remote Sensing Centre, Hyderabad, India. The processing of the above imagery was undertaken by software's like SOCETSET and Global Mapper.

After satellite image processing the products delivered are DTM/DEM, 3D Topographical Features, Orthophoto, which has further been used in finalization of road alignment as per IRC guidelines.

The products from RS has also been played a very critical role in identifying the water bodies crossing the alignments in order to provide cross drainage works to cater for the runoff. Details of the structures for the same are mentioned above in Project details.

Basic summary of the process and technology is as follows:



Appendix

a. *DEM- a relief view - Appendix - 1*
b. *Contours with IBM - Appendix -2*
c. *QC - Check list - Appendix – 3*

Approval / Comments – IIT Delhi

CERTIFICATE

Name of Road: - **DOGINALA-GAU-DAROSI**

Submitted by:	Scrutinized by:
L N Malviya Infra Projects Pvt. Ltd.	IIT – Delhi

Comments (if any):

Suggestions have been incorporated in the report as well as in the drawings

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Geology And Slope Stability By IIT Roorkee

A REPORT ON GEOLOGY AND SLOPE STABILITY ALONG DOGINALA-GAU-DAROSI ROAD SECTION, ARUNACHAL PRADESH

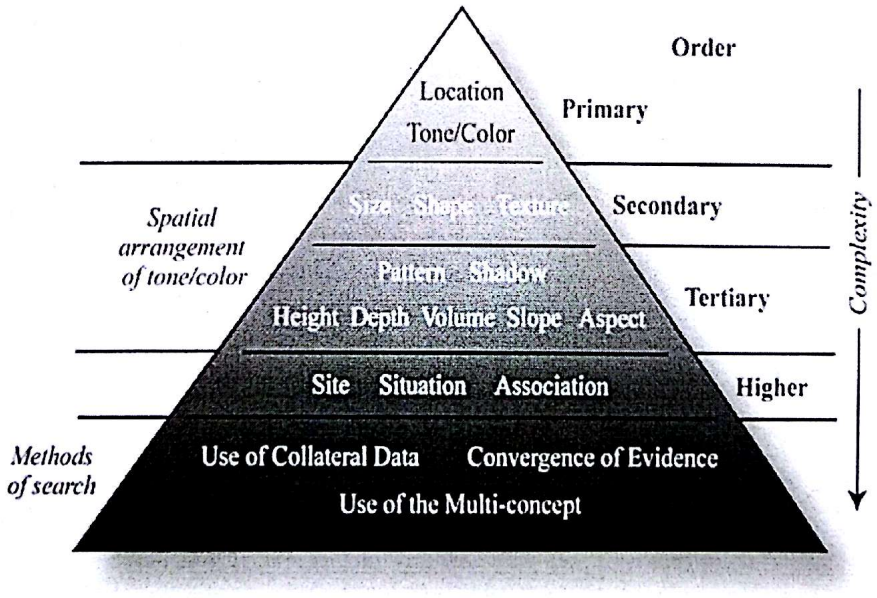
Dr. R. Anbalagan* & Dr. Ajanta Goswami**

INTRODUCTION

The present report deals in detail the methodology and the results of satellite image interpretation of the Doginala-Gau-Darosi road section, Arunachal Pradesh

OBJECTIVE: Study of Geology along the road side (approx. 500 m buffer) and slope stability of adjoining hills using high resolution satellite image

METHODOLOGY. In the proposed study, image interpretation of high resolution GeoEye image was carried out. Image interpretation involves extraction of qualitative and / or quantitative information from an image, which in the present context includes Geology and slope stability. The methodology involved is Deductive Approach which is based on Interpretation Elements (Image Elements & Terrain Elements) coupled with "Convergence of Evidences" criteria. The image elements considered are shape, size, tone, texture, pattern, shadow and association in addition to considering terrain elements such as landforms, drainage, vegetation, land use and soil. The ancillary data used in the study includes geological maps of the area published in refereed journals and GSI maps which are available at 1:50,000 scale. Since the spatial resolution of the ancillary data available is coarse, it was used as supportive information for deduction of Geology and slope stability.



The figure above shows the steps considered for image element interpretation.

Slope stability study can be accomplished successfully using satellite images as shown by McKean et al.(1991), Westen (1993), Soeters and vanWesten, (1996) and Westen (et al., 2008). With reference to the methodology demonstrated by the above

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mentioned researchers, active landslides in the study area are mapped which were seen with characteristic spectral response, mostly show up as bright pixels, typical oval/ elongated shape and association such as close to the river bank/ ridge or at the initiation point of 1st order stream. Many of the old slide zones were interpreted from their triangular/ crescent pattern, fresh vegetation growth and barrenness on the crest region indicating active mass wasting due to head ward erosion.

DOGINALA-GAU-DAROSI ROAD SECTION, ARUNACHAL PRADESH

The Doginala-Gau-Darosi road section in Arunachal Pradesh extends from Doginala Village with an aerial extent of 93°37'54.715"E : 28°34'33.484"N and 93°43'44.528"E : 28°24'6.886"N. This road has a design length of 41.21km (Fig 1).

The road offtakes close to Doginala village, which is located slightly away from the starting point of the road. In fact, this road is entirely located within the valley of a SE to SSE flowing stream course, which joins a major river flowing towards east. It is worth mentioning another stream course flowing towards north is located on the left bank of the major river. This river also joins a major river course close to the offtake point of the road. The road initially located on the right bank of the stream course. Though the river I general has a linear pattern aligned towards N to NNW, it has few zig-zag turns in between, where the side slopes of the stream banks are steep in nature. The stream course on the right bank continues up to 14.35km and passes on to the left bank. Though the road has a linear course initially, it tends to take zig-zag turns wherever the side slopes are steeper on the left bank. The upper levels, the road shifts to right bank again at 22.85km and keeps running on the right bank up to 34.75km. From this location onwards the road moves conspicuously up slopes with a number of U-turns at 36km, 37.4km, and 40.5km and finally reaches 41.21km. The entire alignment looks to be located on a more or less homogeneous terrain with least dissections. The entire stretch looks to be moderate to thickly vegetated with no signs of active landslides. In the final stretch of the road, from 34.10km to 41.2km, the road is located on a single hill slope inclined towards east with numerous zig-zag turns. Since the individual road sections adjoining U-turns are located on a single slope, the road excavation should be well planned and carefully executed to avoid slope instability problems.

The entire road section passes through uniform metamorphic terrain consisting of slates, phyllite and schist. Since these rocks are more prone to weathering, they display a thick vegetation cover on the surface through which the road progresses. Since the terrain looks to be stable the road alignment has been planned systematically on a stable terrain.

Denudational hills, seen on both the side of the valley shows coarse texture due to weathering and erosion. The thin strip of image covering road and buffer area is a challenge to interpret the geology and lithology of the area. Ancillary data used defines the confidence level of interpretation which again depends on the scale. The image provided is partially covered with snow making it difficult to interpret the Geology and slopes. However ancillary data (Geological map and DEM) of the study area could be studied for the deductive approach.

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The break in lithology on either side of river valley could be well deciphered from break in slope, changes in resistance to erosion, changes in drainage pattern and tonal changes. Because of Weathering at places, it becomes soft and fragile locally.

The rocks seem to be deformed and weathered at places along the road alignment. During road construction, suitable precaution may be adopted to minimize slope instability problems due to excavation. Over all the alignment seems to be stable.

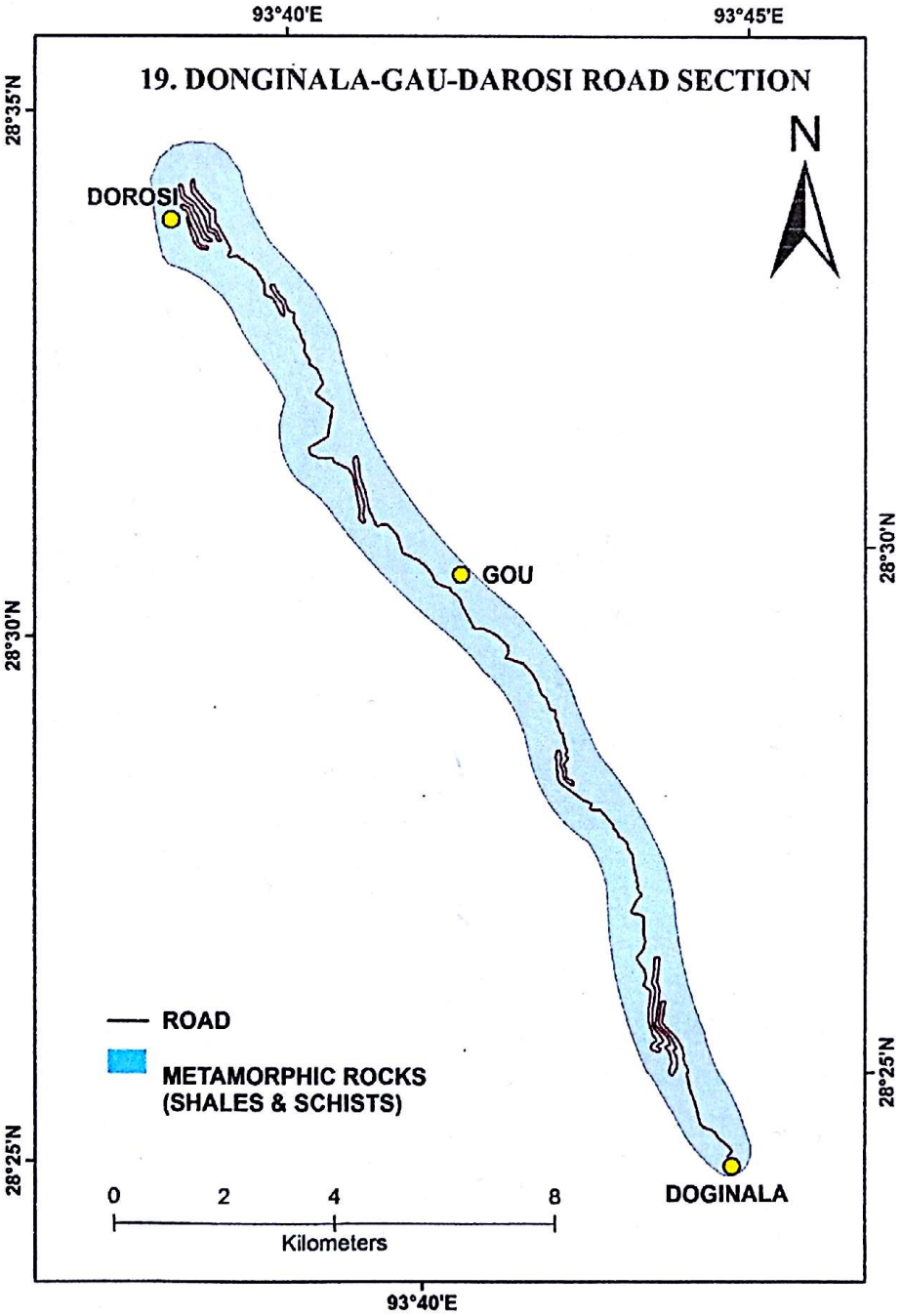

Fig 1: Location and Geology along road section

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Inception Report

INTRODUCTION

Arunachal Pradesh is one of the 29 states of India. Located in northeast India it holds the most north-eastern position among the other states in the north-east region of India. Arunachal Pradesh borders the states of Assam and Nagaland to the south, and shares international borders with Bhutan in the west, Burma in the east and China in the north. Itanagar is the capital of the state.

Arunachal Pradesh is also known as the *Orchid State of India* or the *Paradise of the Botanists*. Geographically, it is the largest among the North-east Indian states commonly known as the Seven Sister States. As in other parts of Northeast India, the people native to the state trace their origins from the Tibeto-Burman people. In recent times, large number of migrants from various parts of India and foreign lands has been affecting the state's population.

The consultancy services for carrying out preparation of Detailed Project Report (DPR) and bid documents to **M/s L N Malviya Infra Projects Pvt Ltd, Bhopal** for Survey, Investigation and Preparation of Detailed Project Report for Improvement of Road and Bridges etc. for construction of High Altitude Hill Roads to Indo-China Border under Phase- II in the state of Arunachal Pradesh using satellite imagery.

The report brings out the project background, mobilization and staffing, approach and methodology relating to surveys / investigations and detailed design. A broad conceptualization of the project essentially based on study of available data/reports and a detailed reconnaissance survey has been provided. The report also makes proposals on issues requiring discussions with the CPWD and decisions necessary for detailing of the project.

The report covers the following major aspects

(i) Project Background
(ii) Mobilization and Progress
(iii) Project Appreciation and Conceptualization
(iv) Proposed Approach and Methodology

PROJECT BACKGROUND

Background

Ministry of Home Affairs (MHA), Govt. of India has decided to take up the development of High Altitude Hill Roads to Indo – China Border.

The Central Public Works Department (CPWD) has been entrusted with the construction of High Altitude Hill Roads to Indo – China Border road in the State of Arunachal Pradesh. This project section is from Doginala to Darosi in the state of Arunachal Pradesh and the total length of proposed road is 35.26 km.

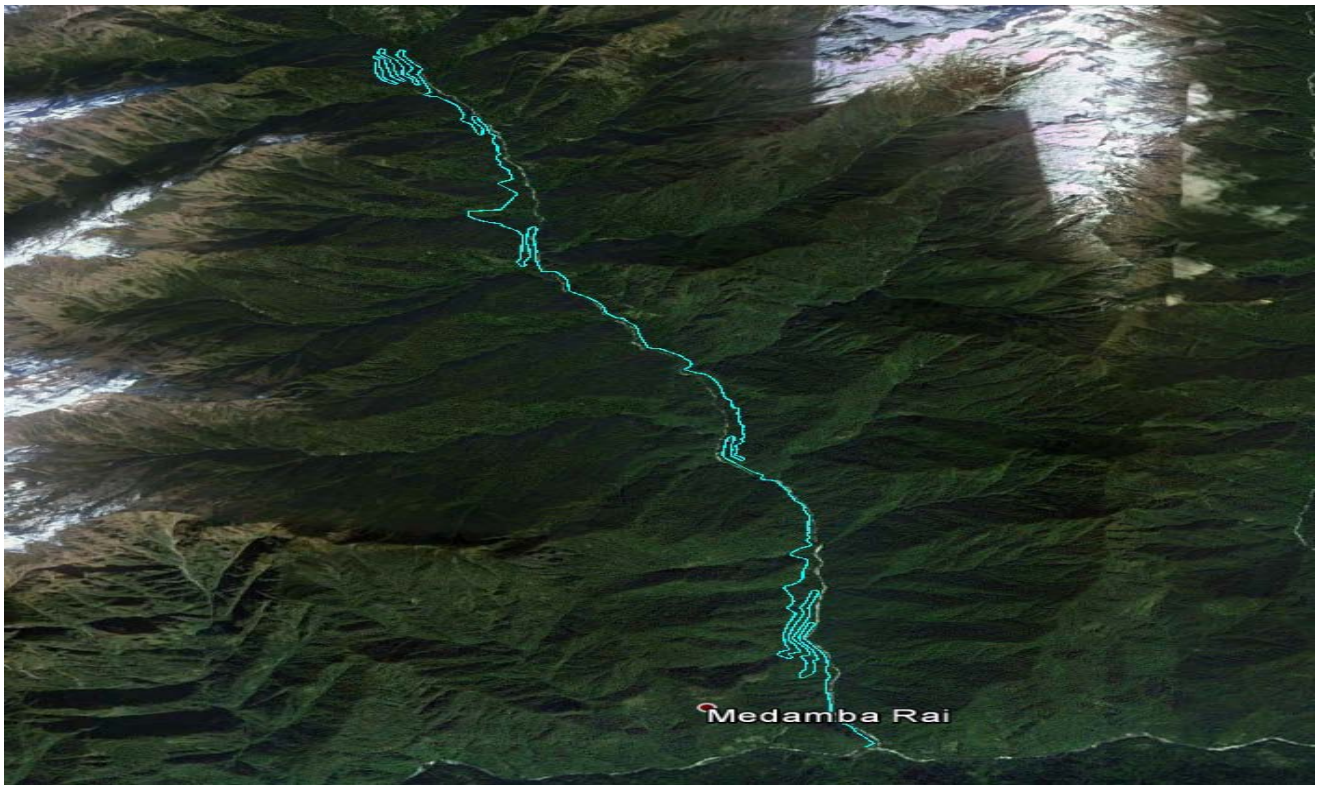
The Coordinates of Project road at starting point, Doginala are Latitude of $28^{O}24'13''$ (North) and Longitude of $93^{O}43'20''$ (East). Coordinates at the end point Darosi are Latitude of $28^{O}33'50''$ (North) and Longitude of $93^{O}38'40''$ (East).

Length provide by ITBP for the road is 50.00 Km, whereas the designed length is 35.26 Km.

Description of the Project Roads

The project road Doginala – Gau – Darosi having length of 35.26 Km. The project stretch is traversing in hilly terrain from Doginala (2423 Ft in height) and ends at Darosi (8232 Ft in height).

The RL difference between two locations is 1771m. The Proposed designed alignment between these station comes out to be 35.26 Km (as shown below in green colour)



Project Alignment of Doginala-Gau-Darosi

Objective of Consultancy Services

The main objectives of the consultancy services is to prepare DPR and bid documents for the length of 35.26 km of Doginala – Gau – Darosi road and to establish the techno, economical, viability of the project and prepare detailed project reports for design of roads and bridges.

An important requirement with regard to improving the Project Road is that the development of work shall be within the Right of Way (ROW) of 18 meter and avoiding additional land acquisition as far as possible. All these means that the development schemes for the Project Road should be as economical as possible consistent with the functional requirements and that it should amenable for quick implementation without delays.

Scope of Consultancy Services

The scope of Consultancy services set out in the RFP, *Inter alia*, includes following major tasks:

1) Engineering surveys and investigations
   - Topographic Survey
   - Hydraulic and Hydrological Investigation
   - Traffic Survey
   - Material Investigations
2) Engineering designs
   - Geometric Designs
   - Pavement and Road Design
   - Design of Bridge and Structures
   - Drainage Design
3) Cost estimation
4) Detailed Project Report and Bid documents

MOBILISATION AND PROGRESS

Commencement

Agreement for the Consultancy services was signed on 11th August 2015. As per the agreement services require to be commenced within 15 days of signing. Letters of Intent (LOI) for commencement of services was issued by CPWD. The effective date of commencement of services for this project is from 11th August 2015 for a period of four months for final submissions of the DPR and Bid Documents.

Mobilization

The Highway Engineer cum Team Leader along with other key personnel were mobilized in the month of September 2015. Preliminary reconnaissance survey was carried out to have a clear understanding of the project requirements and to form the basis of the Inception Report.

The key professionals nominated for the project have staggered input and support staff was inducted according to the manning schedule and project needs. Team of engineers of highway and structural discipline completed the inventory and condition survey of road and structures.

Reconnaissance Survey

A detailed reconnaissance survey of the project roads has been made by the Team Leader, along with the other key personnel during the month of September 2015. A general assessment of the physical, environmental and social conditions along the road was made. Preliminary assessments of the road characteristics and that of cross drainage structures were made through this exercise. The detailed surveys and investigations to be carried out have been planned and executed.

The concerned officials were contacted for necessary secondary data/documents concerning the project roads available with them. The response from them has been encouraging.

Inventory Survey of Road on Bridges/Culverts

Two teams, each comprising of two Engineers have been deployed for collecting all the relevant inventory and conditions survey data of the roads and structures of the project roads.

Improvement Proposal

The data collected from reconnaissance, inventory and condition surveys has been processed for formulating the development proposals for road and structural works.

Topographic survey

The topographic survey of the project alignment / fixing of control points have already commenced from 1st week of September 2015 in the Project Road and completed in October 2015. Our surveyor has been deployed at site as in-charge and to supervise the entire survey works.

PROJECT APPRECIATION AND CONCEPTUALIZATION

General Setting of the Project

Start/ End points and Terrain

The roads which are mentioned in the Contract Agreement under Project is Doginala – Gau – Darosi (length provided by ITBP is about 50.00 Km) in the state of Arunachal Pradesh. The starting point of the Project road is Doginala and ends at Darosi.

The Place Doginala is spread in valley which is surrounded by high hills on East and West side. It is situated in District Upper Subansiri.

Darosi: This is the last point of project stretch and is spread on a wide flat ground (plateau) surrounded by High hills. It is 50.00 Km from Doginala.

Land form

There is no existing road except foot track from Doginala towards Darosi for most of the length except some isolated sections where the conditions is badly damaged. The remaining portion of the project stretch is traversing in hilly terrain (2423 Ft in height) and ends at Darosi (Approx 8232 Ft in height). This stretch is for a length of 35.26 Km. the Place Doginala is spread in valley which is surrounded by high hills on East and West side. It is situated in District Upper Subansiri.

Terrain

Our project road is passing through in hilly terrain throughout the stretch.

Broad Features of the Existing Roads

There is no existing road except foot track.

Existing ROW

During reconnaissance survey, no boundary stones were found. Further, it was confirmed that land for the proposed alignment is yet to be acquired depending upon the design of the alignment, hence no existing ROW.

Cross-Sections for improved facility

Cross-section for the improved facility needs to be adequate to cater for the traffic expected over the design period and offer safe and convenient traffic operations at speeds consistent with terrain condition.

Cross-section for Cross-drainage Structures

Based on inventory and condition survey, causeways and drainage structures have been proposed to cater the water discharge.

PROPOSED APPROACH AND METHODOLOGY

General Approach

The general approach of the Consultants would be to comprehensively address the various issues involved in the project, to carry out all the field and design office activities as set out in the Scope of Services of the TOR, and finally to develop improvement proposals satisfying the objectives of the project.

Methodology

General

The project involves a series of inter-related activities, both in the field and in the design office. Methodology for carrying out these activities is described in the following paragraphs.

Topographical Surveys

The topographical surveys by means of GPS, for fixing of ground control points for the entire length of the corridor. Further, the survey has been completed with the 0.5 m high resolution satellite imagery.

Soil and Material Investigations

Prospective sources of construction materials have been located by the Consultants to add in list of sources of materials.

To estimate the quantities of available suitable materials, the Consultants have prepared quarry/material source charts including lead distances etc. This shall form an input in Rate Analysis of the borrow / quarry materials, following which recommendations for the use of the materials from different sources can be made.

Material investigation done for engineering properties reveals that the material available at site is fit for use in protection, drainage and surfacing works aggregate and no quarry outside the site is required. The material can be used for crust layer execution by processing the available material by stone crusher and rotary screen. Only local transportation is the need for transporting the aggregates for preparation of Bituminous mix preparation and laying at respective chainages. (Site soil report is on page no.78.)

Design Standards

The project stretches located in the state of Arunachal Pradesh. Design standards for most elements of such road categories have been adopted from the IRC, MoRT&H. It is, therefore, more of an exercise to compile the standards for the related components as applicable to the terrain, environs and improvement options of the project.

Geometric Design

Geometric design has carried out as per IRC: SP: 48:1998 and using suitable software i.e., MX Road, Auto Cadd etc and the following activities have constituted the design process:

- *Fixing the final centerline of the proposed road with due regard to flattening sharp horizontal curves to the extent possible.*
- *Fixing the final profile for the proposed road with appropriate grades/sight distance.*
- *Design of horizontal and vertical alignment.*
- *Finalizing and fixing the typical cross-sections.*
- *Developing the final alignment for the improved facility, showing centerline, carriageway and roadway lines, toe lines, etc. Visibility splays at inside of curves will be designed to provide needed sight distance.*

It is mentioned that all designs have been carried out with a view to avoid additional land acquisition.

Pavement Design

Pavement design has covered the following activities:

Parameters for Design

i) Design Life

As the project-road mostly located in hilly terrain so as per *Hill Road Manual*, IRC: SP: 48-1998 deign life of hill roads shall be of 15 years.

ii) Design Traffic

As there is no existing road, resulting **NIL** traffic on this stretch. However, as a bare minimum, we have adopted the traffic density of 5 MSA for designing of crust thickness in accordance with the guidelines of Ministry of Road Transport & Highways and IRC: 37:2012.

iii) Subgrade Strength

For design of new pavements, soaked CBR over homogenous soil stretches were adopted along with the design traffic. The pavement composition shall be as per IRC: 37: 2012.

Drainage Design

A suitable drainage system consists of surface as well as subsurface drainage has been designed. There are various aspects of surface drainage, which have been elaborated below. The sub surface drainage is the drainage arrangement made for discharging the water that percolates down beneath the road surface. This will generally be achieved by extending the GSB course to the full width of the pavement to permit intra pavement drainage. However, for this project extensive provisions shall be made for sub-surface/subgrade drainage and to take care of seepage through the adjacent hill face of the road and underground water flows. Provision of non- woven geo textile 125 micron as per manufacturer specification has also been kept at the appropriate places.

There are three aspects of surface drainage design in which particular attention needs to be given for the road section. **First** is the fast dispersal of precipitation on the road surface so as to avoid hydroplaning and minimize the danger to the moving vehicle. This is achieved by proper geometric design of the road, e.g. by crowning the carriageway or one side cross fall, giving proper cross slope to the shoulders, providing requisite longitudinal gradient etc. **Second** is the water from road and the surrounding area shall be successfully intercepted and led away to the natural outfalls. This is achieved by a system of suitable surface drains; shallow ditches by the side of roads or deep catch water drains on the hill slopes. Thirdly adequate cross drainage structures should be build across river crossing and minor streams. This is done by suitably identifying the valley points where causeways will be required.

The runoff resulting from the rainfall poses severe risk to the road section. The runoff originating from the road surface has therefore to be channelized and transferred into a cross drainage structure or natural outlet without causing damage to any element of the road and/or adjoining properties. This is done by properly designing the surface drainage system, which includes drains, discharging structures and transfer structures.
The drainage study for the project will be based on:

- *General topographical features of the area*
- *Proposed drainage facilities/ structures*

The requirement of various types of drainage arrangement will depend upon the embankment height, type of soil, ground water table, and topography of the adjacent ground near the proposed alignment. V-type drain which is currently in use in the hill sections has been proposed.

It may also be noted that there is always a natural drain of surface water due to the longitudinal profile at hill sections. This has been adequately addressed, which consequently reduce the drain sections.

Traffic Safety Features and Road Furniture

In hill roads, after developing, speed of vehicles generally increases. Due to natural instinct, vehicles land to over speed. Thus safety features and road furniture play important role in such roads.

Therefore, we have considered these aspects and prepared the designs and drawings for the following items:

- *Road Signs*

  These would include mandatory, warning and informatory signs according to Indian Motor Vehicles Act.
- *Guard Post & Metal Beam Crash Barrier*

  The road being is hilly terrain, concrete guard posts are required almost at all stretches including high embankment locations / cutting locations. Metal beam crash barriers have been proposed at on outer side of sharp horizontal curves.

- *Concrete Parapet*

  Concrete Parapet on valley side as is currently in use has also be considered, particularly where there is deep valley side.

Machineries Required for Construction of Road

General

Construction of roads in hills are machine based with an appropriate mixture of labour due to the following main factors:-

1. Non-availability of adequate local labour
2. Difficult terrain/remote areas
3. Severe climatic conditions
4. Non-availability of infrastructure to sustain labour

In most of the hilly areas, labour has to be imported from plains due to scarcity of local labour. Such labour takes long time to acclimatize and their output is also comparatively lower. Thus use of labour intensive methods in hilly areas in often not economical and takes longer duration. The terrain in hilly areas is generally difficult. The construction of roads in some areas requires extensive blasting and the roads have to be carved through very steep and vertical rock faces. Thus exclusive dependence on manual labour for work in hilly areas has safety hazards. Due to severe climate conditions in most of the hilly areas, the fair weather period available for work is also low. Some of the hilly areas have heavy rainfall or snow-fall for major part of the year. Since the time available for work is very limited, **mechanization** is a rather a necessity to achieve high productivity during the available short time.

Mechanized Method

On major projects, the work of bulky and repetitive nature can be done more economically and efficiently by well-designed machines. The use of machines also greatly reduces logistic problems. Partially every operation in construction of roads can be performed by different types of equipment, but under any given set of conditions only a particular type of machine would be most effective. Thus selection of machines for any particular phase of construction requires detailed study about brands, models and specifications of the various equipment available and their suitability for particular phase of construction. IRC publication “Handbook on Road Construction Machinery” of MoRT&H may be referred for further details.

A list of plant and equipment commonly required for different phases of mechanized construction are as follows:-

A. Formation cut/embankment

1. Jungle Clearance
2. Formation cutting, excavation/ embankment
3. Scraper, tractor/ motorized or towed
4. Wheel dozer.

5. Excavator with shovel/drag-line attachment
6. Pay loader – (Front end loader)
7. Water Lorries
8. Water pump
9. Motor grader
10. Compactor, Vibratory roller and smooth wheel roller (8/10 tonne capacity)

(a) Blasting

1. Air Compressor
2. Wagon drill
3. Jack hammer with accessories
4. Exploder with shot firing cable
5. Ohm-meter

B. Protective and drainage works

1. Excavator
2. Back hoe loader
3. Concrete mixer
4. Tripod pulley block/crane
5. Truck mounted mixers
6. Vibrators internal and screed type
7. Fork lift
8. Water lorries
9. Bar bending, Bar straightening and Bar cutting machine
10. Water pump
11. Load Carriers (Dumper/Tipper & Trucks)

C. Flexible Pavement – (Pavement with bituminous surfacing)

1. Crushing of aggregate
2. Stone crusher with all accessories - 100 TPH
3. Granulators
4. Air Compressor
5. Jack hammer with accessories
6. Blasting accessories
7. Tractor with dozer attachment, wheel dozer
8. Pay loader (front end loader)
9. Load carriers (Dumper/ Tipper & Trucks)
10. Generator

(a) Laying base/sub-base courses

1. Grader
2. Water bower with water sprinkling system

3. Disc horrow/ rotary tillers
4. Paver finisher
5. Compactors-3 wheeled smooth roller 8/10 tonne capacity and vibratory roller
6. Mixer for wet-mix macadam – 40 to 60 TPH
7. Load Carriers
8. Bitumen Work
9. Bituminous heating and handling equipment
10. Bitumen tanker (in case of bulk supply arrangement)
11. Bitumen boiler
12. Mastic cooker (in case of mastic asphalt and poly-sulphide sealant)

(b) Bitumen spraying and mixing equipment

1. Bitumen pressure distributor
2. Gritter
3. Hot mix or cold mixing plant of appropriate capacity (60 TPH to 90 TPH or 90 TPH to 120 TPH) with all accessories as laid down in IRC:SP-24
4. Dumper/ Tippers and Trucks
5. Spreading and laying bituminous courses
6. Paver finisher

D. Rolling Equipment and pavement marking equipment

i. Three wheeled roller, 8/12 tonne
ii. Tandem roller
iii Vibratory roller
iv. Pneumatic tyre roller
v. Pavement marker

E. Tools for checking surface evenness and density/ compaction

i. Profilometer
ii. Density meter

The surface unevenness and compaction are generally checked with camber board/template, straight edge, depth gauge and density measuring kit. Recently unevenness indicator and nuclear density maters have also been introduced for exercising quality control.

F. Tools and appliances for safety during construction. These are common to all activities and are listed below:

1. Road barriers
2. Diversion boards
3. Caution boards
4. Red flags

5. Red lamps
6. Field tent and accessories
7. Gum boots
8. Gloves
9. Goggles
10. First aid box
11. Oxygen kit for high altitude of work

Time Estimate:

The time estimate for this road has been worked out based on the terrain, accessibility and length of road, weather conditions etc. the work has been divided into two portions, i.e.

(i) Formation cutting, cross drainage works and protection works
(ii) Pavement crust (sub-base, Base and wearing course)

Going by the experience of Phase - I roads, the average time per km is seen to be in the range of 6 - 7 km per working seasons in the tough terrain conditions.

Regarding the present alignment, it is accessible for approx 6 months only.

Hence, time taken for formation cutting cross drainage works and protection works is 6 working seasons and two working season shall be for pavement crust.

Accordingly, 7 years construction period has been considered for this alignment.

Survey Data Report

SUMMARY OF SURVEYAND INVESTIGATION DATA

General

Following are the various Engineering Surveys and Investigations required has been conducted for completion of Detailed Project Report.

- Reconnaissance and Alignment,
- Road and Pavement Investigations,
- Investigation for Bridges and Structure,
- Material Investigation,
- Public Liaison

Reconnaissance and Alignment

The Project road Doginala – Gau - Darosi Road starts from Doginala and terminates at Darosi.
The actual design length of the proposed alignment is 35.26 km.

Satellite Imagery

General:

(a) The beneficiary of the roads will be paramilitary forces and therefore the coordination in field with ITBP establishment and their association is vital for QA will to attain positive outcome in the project. We have worked in close coordination with ITBP authorities.

(b) Owing to the “area of interest” located in high altitude in the Border States possibility were explored for all avenue of satellite imagery interpretation.

(c) The procurement of satellite data/Imagery of the high resolution of 0.5 meter resolution has been done through NRSC Hyderabad. We have interacted directly with National Remote Sensing Centre, Hyderabad in this regard.

(d) The procurement cost of these imagery/stereo pair has borne by us. However documentary proof of procurement of these high resolution imageries and actual expenditure incurred on their procurement viz cash memo, vouchers have been submitted to CPWD.

(e) The confidentiality clause has followed in letter and spirit by one and all to ensure confidentiality of the data.

The DEM alignment has fixed on the satellite imagery by us along with the details of coordinates fixed with differential Global Positioning System.

Particular TOR for Satellite Imagery

- The coordinates of the origin and destination points of the proposed roads provided in the TOR were tentative. These have been checked on ground by us in concurrence of ITBP posts at the particular stations by GPS to ensure the accuracy of the coordinates.

- We have conducted exercise on Google Pro and provided alternate alignments including the considerations of pro and cons of the alignments. The details of pros and cons and the proposed alignment had submitted by us to CPWD for evaluation and finalization particularly to locate the Centre line coordinates of the said alignment.
- These coordinates were selectively checked for ground validation/trotting at every 5 km.
- The geology of the area and potential landslide prone areas was kept in view while deciding the alignment. The potential landslide hazard zone, if coming in the alignment has avoided and the possible alternative were explored in deciding the alignment. All bottlenecks in the connectivity have removed for through operation of road being planned after put it into use.
- Identification of the land requirement and the affected properties requiring resettlement and rehabilitation and acquisition of land from forest and private land owners were also addressed.
- The route marked on the Google pro has transferred by us on the recent high resolution coloured satellite imagery/stereo pair of 0.5 m resolutions procured by us and it reflected present conditions of the site. The satellite stereo pair images and sharpened images procured for the ground profile and geographic features along the corridor have linked. Based on geographic features extracted from sharpened images and ground profile from the high resolution colored satellite stereo-pair images, the horizontal and vertical alignment has designed on this satellite imagery.
- The high resolution colored stereo satellite imageries/stereo pair of 0.5m resolution and 5 km corridor width, has procured by us for generation of the Digital Terrain Model (DTM) of 5 meter Grid.
- We have generated the DEM alignment on the satellite imagery by internationally accepted and time tested software.
- The services of the specialized data interpreter have arranged by us to conduct the exercise of DEM alignment and other works on satellite imagery. The DEM alignment has fixed on the satellite imagery by us along with the details of coordinates fixed with differential GPS system.
- The exercise of superimposing the data of Stereo Ortho kit of particular photo image with ortho-corrected imagery, to prepare the ortho-rectified satellite imagery and DEM model including 3D modeling for interpretation of the images has done by us.
- The linkage of coordinates with differential GPS enables instrument having static accuracy ±3mm+0.1 ppm (horizontal) & ±3.5mm+0.4ppm (vertical) and Real Time Kinematic (RTK) ±8mm+1ppm (horizontal) & ±15mm+1ppm (vertical) were remain the responsibility of us.
- The 3-D model generation in the Digital Elevation Model (DEM) alignment has been done by us at every 10 meter interval and every sharp curve and hair pin bends and coinciding the natural features.
- The contour generation at an interval of 2.50 m has been done by us and the spot height at an interval of half the contour interval. The corresponding check has also done by us on 3-D model generated at every 15 m.

- We have conducted aerial Triangulation in the satellite imageries to refine the Exterior Orientation parameters (X, Y, and Z) computed through direct geo referencing for each imagery to help in achieving the desired accuracy while generating DTM. This operation included measuring and transferring all tie, check, and control points appearing on all photographs manually; and performing a least squares block adjustment. This process ultimately provided exterior orientation parameters for satellite stereo-pair and three-dimensional co-ordinates for measured object points.

Inventory and Condition Survey of Road and Pavement

Road Width & Shoulder

On the project road (Doginala – Gau - Darosi), as it is entirely new alignment and there is only a foot track, there is no traffic plying on this section.

Terrain

The terrain is mountainous and has steep gradients.

Land use

The proposed alignment is a link for Doginala – Gau - Darosi. There is no wild life/century across the proposed alignment. There is only forest land across the alignment except few locations which is private land. The details of land use pattern along the project road are-

- Agricultural land – 0.00 %
- Private Land – 3.00 %
- Forest Land – 97.00 %

Origin-Destination Survey

Not applicable

Feasibility Report

PROJECT ALIGNMENT DESCRIPTION

The Project Doginala to Darosi Road starts from Doginala & terminates at Darosi in the state of Arunachal Pradesh.

The actual design length of the proposed alignment is 35.26 km.

The consultancy services for the same have included design of best possible alignment and pavement composition, culverts and other structures in addition to analysis of costs, determining project feasibility.

Alignment deciding criteria/factors

1. Connectivity to ITBP Posts.
2. Stable side of hill
3. Avoiding of S –bends to the extent possible.
4. Gradient limits
5. Availability of road construction materials.
6. Minimum number of cross drainage structures.
7. Connectivity to intermediate village, if any.
8. Avoiding acquisition of private land.
9. Keeping the alignment 25-30 m above normal water level of river, if any.

Chainage References

Chainage References (Doginala – Gau – Darosi)

Sr. No	Design Chainage (km)		Remarks
	From	To	
1	Doginala Ch.0+000 E - $93^0$43’20’’ N - $28^0$24’13’’ Z – 738.713 m	Darosi Ch.41+210 E - $93^0$38’40’’ N - $28^0$33’50’’ Z – 2509.884 m	Forest Land

Right Of Way [Row]

Proposed ROW for the construction of road is taken 18.00 m and finished road width 6.25 m as per provision in IRC 48-1998.

Abutting Land Use Pattern

The proposed alignment is a link between Doginala – Gau - Darosi. The pattern on both side of road is hill. The details of land use pattern along the project road are-

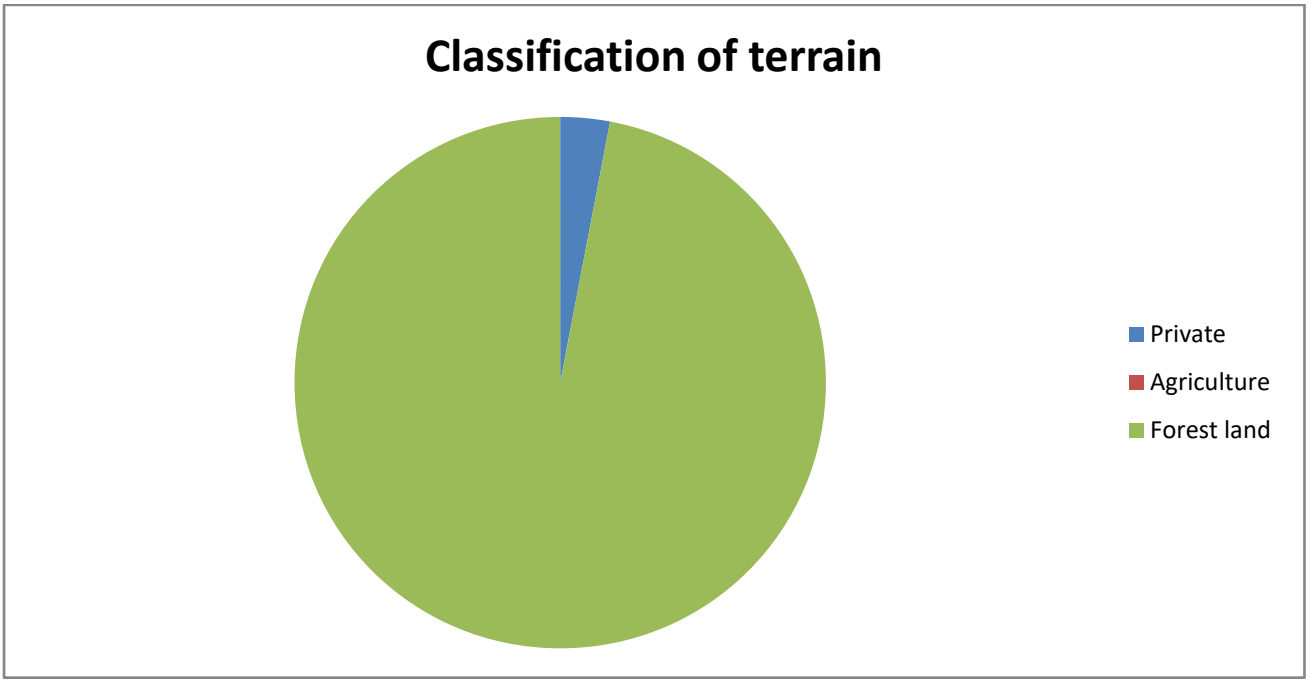


Table: Existing Land Use Pattern (Doginala - Gau – Darosi)

Terrain

The terrain is mountainous throughout the proposed alignment.

Land Acquisition Plan

As per clause no. 2.4 of TOR, the data collection for land acquisition plan is in progress and shall be submitted as a supplementary report as the location is in remote area and accessibility is quite difficult to gather all the required information.

Sliding/Avalanches Zone

The proposed alignment does not pass through any sliding/avalanches zone. We have shifted the proposed alignment to the extent possible from any such location for durability of road.

Important Settlements

There is no settlement/village/habitation along the alignment.

Traffic

The proposed road is entirely new proposal that has to be constructed and hence there is **no traffic**.

Pavement Compositions

As per clause no 10.22.3.1 of IRC: SP: 48- 1998, Hill road manual, In high altitude area which are subjected to heavy snowfall, sub zero temperature, frost action, snow drifts and avalanche activities, design and construction of pavement require special consideration.

The method of design followed is a modification of the CBR method incorporating mechanistic approach. The

empirical pavement design presented in IRC: 37-2012. "GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS" (Second Revision) has been extended to cater design traffic up to 5 MSA using analytical design method and has been followed for this project.

The traffic used in design is in terms of the cumulative number of standard axles to be carried during the design life of the road.

As per clause no 10.22.3.5 of IRC: SP: 48- 1998, Hill road manual, depth of construction (pavement) should not be less than depth of frost-penetration and should compose of non –frost suitable materials, In no case the thickness should not be less than 450 mm.

Crust design has been done based on the field CBR evaluated from the samples collected from site during field survey at every 1.0 Km interval and critical CBR has been adopted for crust design in accordance with IRC - 37:2012, using 10% CBR for sub grade and from the curves as mentioned in IRC: 37- 2012 pavement thickness were computed for the relevant million standard axles and pavement thickness required for the above designed MSA and as per IRC guidelines is shown in following table.

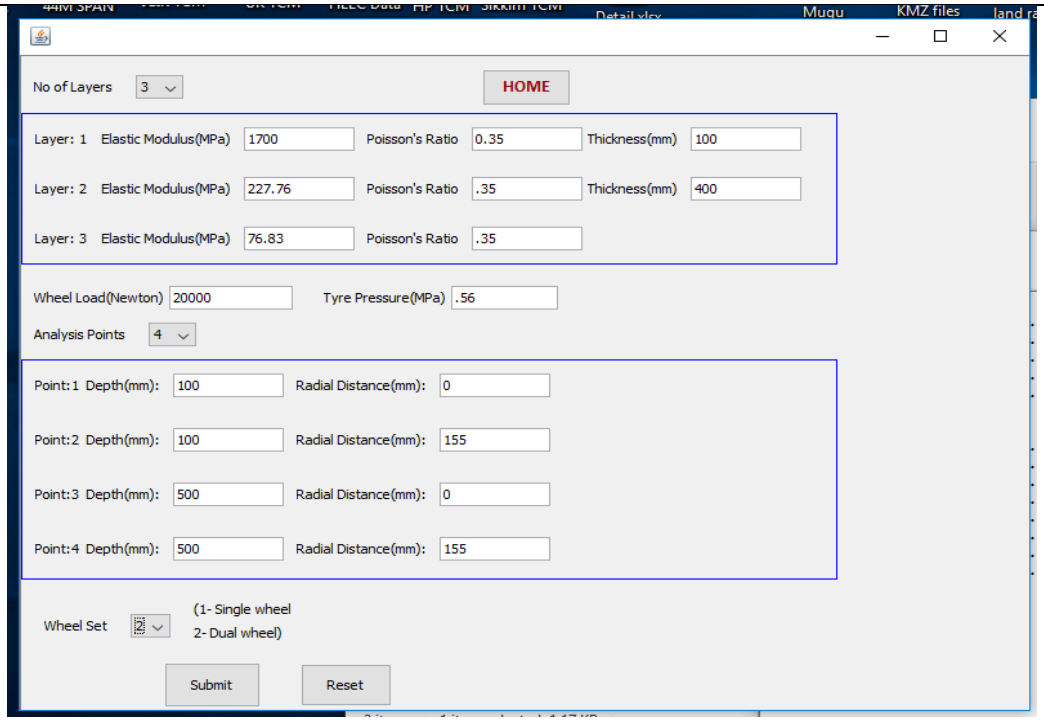
However, as per clause no 1.5 and 2.1 of IRC: 37-2012, there is clearly mentioned that the local environment and past pavement performance in the respective region must be considered, while selecting a pavement thickness. Hence, as the proposed road mostly falls under snow prone area, the wearing course should be of higher thickness. Further, due to unavailability of binder material, WMM or WBM can't be feasible. So based on the surrounding circumstances and availability of required construction material following thickness of crust has been adopted.

SN	Section	Adopted MSA	Adopted CBR (%)	Pavement Composition (mm)			
				BC	DBM	CRM	GSB
1	*Doginala- Gau - Darosi*	5	10%	40	60	200	200

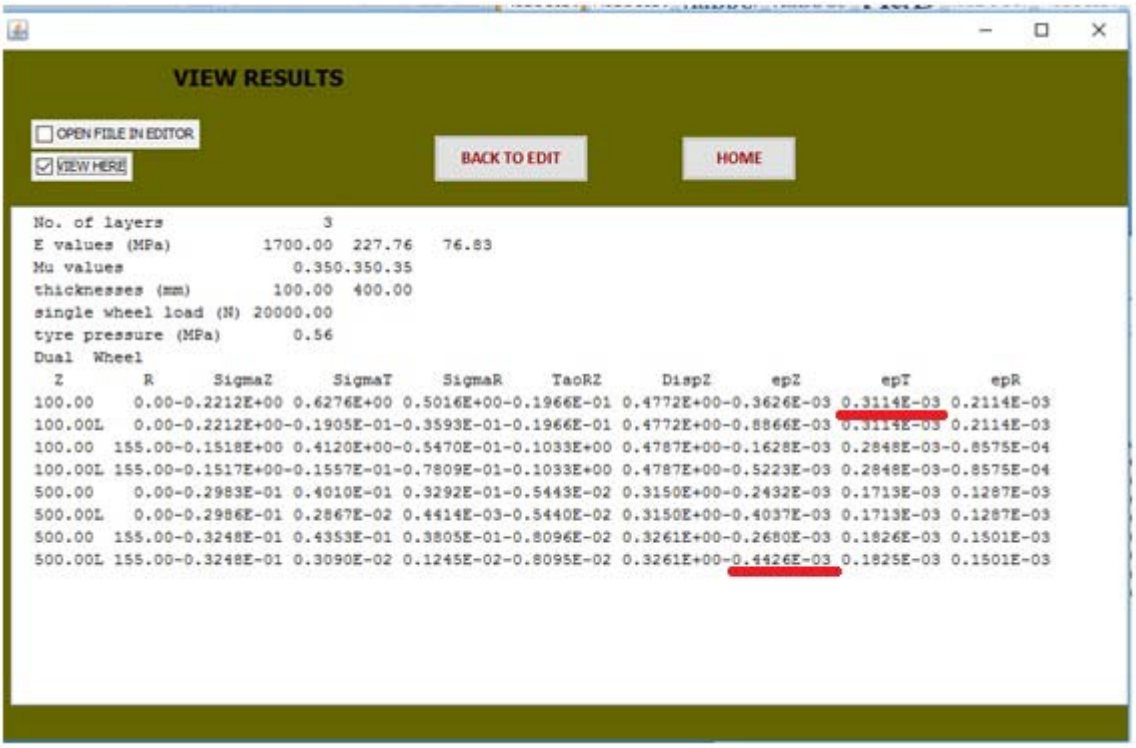
Design of Pavement through IITPAVE

The design of the pavement has been checked with IITPAVE software as per IRC 37 - 2012 - Section 9 and the results are as follows:

INPUTs:



OUTPUT:



Further, the same has been done manually and the results are as follows:

Description	Values	Reference
Design Period	15 Years	

Description	Values	Reference
Design Traffic for Bituminous layers (MSA)	5	
Design Traffic for Base and Sub-base layers(MSA)	5	
Effective CBR of Subgrade	10	
Grade of Bitumen	VG - 10	
Pavement Crust (mm)		
Granualar Subbase (GSB)	200	As per Crust composition considered
Crusher Run Macadam (CRM)	200	
Dense Bituminous Macadam (DBM)	60	
Bituminous Concete (BC)	40	
Resilient Modulus in Mpa of		
Subgrade	76.83	As per Eq. 5.2
Base course (CRM+GSB)	227.76	As per Eq. 7.1
Bituminous Layers (DBM & BC)	2000.00	As per Table 7.1
Poissons Ratio (μ) of		
Subgrade	0.35	As per Table VIII - I (Annexure - VIII)
Base course (WMM+GSB)	0.35	
Bituminous Layers (DBM & BC)	0.35	
Allowable Strains		
Horizontal tensile strain at the bottom of DBM layer (εt)	410.63E-06	As per Eq. 6.1
Vertical strain at top of subgrade (ε_v)	784.38E-06	As per Eq. 6.4
Computed strains from IITPAVE software		
Horizontal tensile strain at the bottom of DBM layer (εt)	311.4×10^{-6}	
Vertical strain at top of subgrade (ε_v)	442.6×10^{-6}	

As the strains computed through IITPAVE are less than calculated strains as per IRC 37, the design is SAFE.

Cross Drainage Works

There are total 35 no's of Hume Pipe Culvert and 107 no of Slab Culvert of following length that are being proposed in this alignment for cross drainage works.

Slab Culvert (1X3m) - 107 No's

Hume Pipe Culvert (1 x 1200m) - 35No's

PROPOSED STRUCTURE LIST

SR.NO	*Chainage*	*TYPE OF STRUCTURE*	*SPAN LENGTH*
1	0+000	Slab	1 x 3 m
2	0+250	Slab	1 x 3 m
3	0+500	Slab	1 x 3 m
4	0+750	Pipe	1 x 1200 mm
5	1+000	Slab	1 x 3 m
6	1+250	Slab	1 x 3 m
7	1+500	Slab	1 x 3 m
8	1+750	Pipe	1 x 1200 mm
9	2+000	Slab	1 x 3 m
10	2+250	Slab	1 x 3 m
11	2+500	Slab	1 x 3 m
12	2+750	Pipe	1 x 1200 mm
13	3+000	Slab	1 x 3 m
14	3+250	Slab	1 x 3 m
15	3+500	Slab	1 x 3 m
16	3+750	Pipe	1 x 1200 mm
17	4+000	Slab	1 x 3 m
18	4+250	Slab	1 x 3 m
19	4+500	Slab	1 x 3 m
20	4+750	Pipe	1 x 1200 mm
21	5+000	Slab	1 x 3 m
22	5+250	Slab	1 x 3 m
23	5+500	Slab	1 x 3 m
24	5+750	Pipe	1 x 1200 mm
25	6+000	Slab	1 x 3 m
26	6+250	Slab	1 x 3 m
27	6+500	Slab	1 x 3 m
28	6+750	Pipe	1 x 1200 mm
29	7+000	Slab	1 x 3 m
30	7+250	Slab	1 x 3 m
31	7+500	Slab	1 x 3 m
32	7+750	Pipe	1 x 1200 mm
33	8+000	Slab	1 x 3 m
34	8+250	Slab	1 x 3 m
35	8+500	Slab	1 x 3 m
36	8+750	Pipe	1 x 1200 mm
37	9+000	Slab	1 x 3 m
38	9+250	Slab	1 x 3 m
39	9+500	Slab	1 x 3 m
40	9+750	Pipe	1 x 1200 mm
41	10+000	Slab	1 x 3 m
42	10+250	Slab	1 x 3 m
43	10+500	Slab	1 x 3 m
44	10+750	Pipe	1 x 1200 mm
45	11+000	Slab	1 x 3 m
46	11+250	Slab	1 x 3 m
47	11+500	Slab	1 x 3 m
48	11+750	Pipe	1 x 1200 mm
49	12+000	Slab	1 x 3 m
50	12+250	Slab	1 x 3 m
51	12+500	Slab	1 x 3 m

PROPOSED STRUCTURE LIST

SR.NO	*Chainage*	*TYPE OF STRUCTURE*	*SPAN LENGTH*
52	12+750	Pipe	1 x 1200 mm
53	13+000	Slab	1 x 3 m
54	13+250	Slab	1 x 3 m
55	13+500	Slab	1 x 3 m
56	13+750	Pipe	1 x 1200 mm
57	14+000	Slab	1 x 3 m
58	14+250	Slab	1 x 3 m
59	14+500	Slab	1 x 3 m
60	14+750	Pipe	1 x 1200 mm
61	15+000	Slab	1 x 3 m
62	15+250	Slab	1 x 3 m
63	15+500	Slab	1 x 3 m
64	15+750	Pipe	1 x 1200 mm
65	16+000	Slab	1 x 3 m
66	16+250	Slab	1 x 3 m
67	16+500	Slab	1 x 3 m
68	16+750	Pipe	1 x 1200 mm
69	17+000	Slab	1 x 3 m
70	17+250	Slab	1 x 3 m
71	17+500	Slab	1 x 3 m
72	17+750	Pipe	1 x 1200 mm
73	18+000	Slab	1 x 3 m
74	18+250	Slab	1 x 3 m
75	18+500	Slab	1 x 3 m
76	18+750	Pipe	1 x 1200 mm
77	19+000	Slab	1 x 3 m
78	19+250	Slab	1 x 3 m
79	19+500	Slab	1 x 3 m
80	19+750	Pipe	1 x 1200 mm
81	20+000	Slab	1 x 3 m
82	20+250	Slab	1 x 3 m
83	20+500	Slab	1 x 3 m
84	20+750	Pipe	1 x 1200 mm
85	21+000	Slab	1 x 3 m
86	21+250	Slab	1 x 3 m
87	21+500	Slab	1 x 3 m
88	21+750	Pipe	1 x 1200 mm
89	22+000	Slab	1 x 3 m
90	22+250	Slab	1 x 3 m
91	22+500	Slab	1 x 3 m
92	22+750	Pipe	1 x 1200 mm
93	23+000	Slab	1 x 3 m
94	23+250	Slab	1 x 3 m
95	23+500	Slab	1 x 3 m
96	23+750	Pipe	1 x 1200 mm
97	24+000	Slab	1 x 3 m
98	24+250	Slab	1 x 3 m
99	24+500	Slab	1 x 3 m
100	24+750	Pipe	1 x 1200 mm
101	25+000	Slab	1 x 3 m
102	25+250	Slab	1 x 3 m

PROPOSED STRUCTURE LIST

SR.NO	*Chainage*	*TYPE OF STRUCTURE*	*SPAN LENGTH*
103	25+500	Slab	1 x 3 m
104	25+750	Pipe	1 x 1200 mm
105	26+000	Slab	1 x 3 m
106	26+250	Slab	1 x 3 m
107	26+500	Slab	1 x 3 m
108	26+750	Pipe	1 x 1200 mm
109	27+000	Slab	1 x 3 m
110	27+250	Slab	1 x 3 m
111	27+500	Slab	1 x 3 m
112	27+750	Pipe	1 x 1200 mm
113	28+000	Slab	1 x 3 m
114	28+250	Slab	1 x 3 m
115	28+500	Slab	1 x 3 m
116	28+750	Pipe	1 x 1200 mm
117	29+000	Slab	1 x 3 m
118	29+250	Slab	1 x 3 m
119	29+500	Slab	1 x 3 m
120	29+750	Pipe	1 x 1200 mm
121	30+000	Slab	1 x 3 m
122	30+250	Slab	1 x 3 m
123	30+500	Slab	1 x 3 m
124	30+750	Pipe	1 x 1200 mm
125	31+000	Slab	1 x 3 m
126	31+250	Slab	1 x 3 m
127	31+500	Slab	1 x 3 m
128	31+750	Pipe	1 x 1200 mm
129	32+000	Slab	1 x 3 m
130	32+250	Slab	1 x 3 m
131	32+500	Slab	1 x 3 m
132	32+750	Pipe	1 x 1200 mm
133	33+000	Slab	1 x 3 m
134	33+250	Slab	1 x 3 m
135	33+500	Slab	1 x 3 m
136	33+750	Pipe	1 x 1200 mm
137	34+000	Slab	1 x 3 m
138	34+250	Slab	1 x 3 m
139	34+500	Slab	1 x 3 m
140	34+750	Pipe	1 x 1200 mm
141	35+000	Slab	1 x 3 m
142	35+240	Slab	1 x 3 m

Design Parameters

Following design standards have been adopted as per Indian Roads Congress (IRC) Guidelines, contained in IRC: 73, IRC: 86, IRC: 38 and IRC: SP: 23 and are given in Table below:

Table- Design Parameters

Sl. No.	Item	Mountainous/Steep Terrain
1	Design speed (kmph)	30 Kmph, As per IRC:SP:48-1998, sub clause 6.3.1
2	Right of Way	18.00 m
3	Width of carriageway (m)	3.75 m
4	Paved shoulders	Nil
5	shoulders	2 x 1.25 m
6	Camber/cross fall	
(i)	Carriageway & paved shoulders	2.0%
(ii)	Earthen shoulders	2.5%
7	Maximum super elevation	7%
8	Minimum Radii of horizontal curves (m)	30m Ruling /20m Absolute min.
9	Minimum length of vertical curves (m)	15 m
11	Drains	As per Design
12	Sight Distance	As per IRC:SP:23
13	Gradient	
(i)	Ruling Gradient	5%
(ii)	Limiting Gradient	6%
(iii)	Exceptional Gradient	7%

SALIENT FEATURE

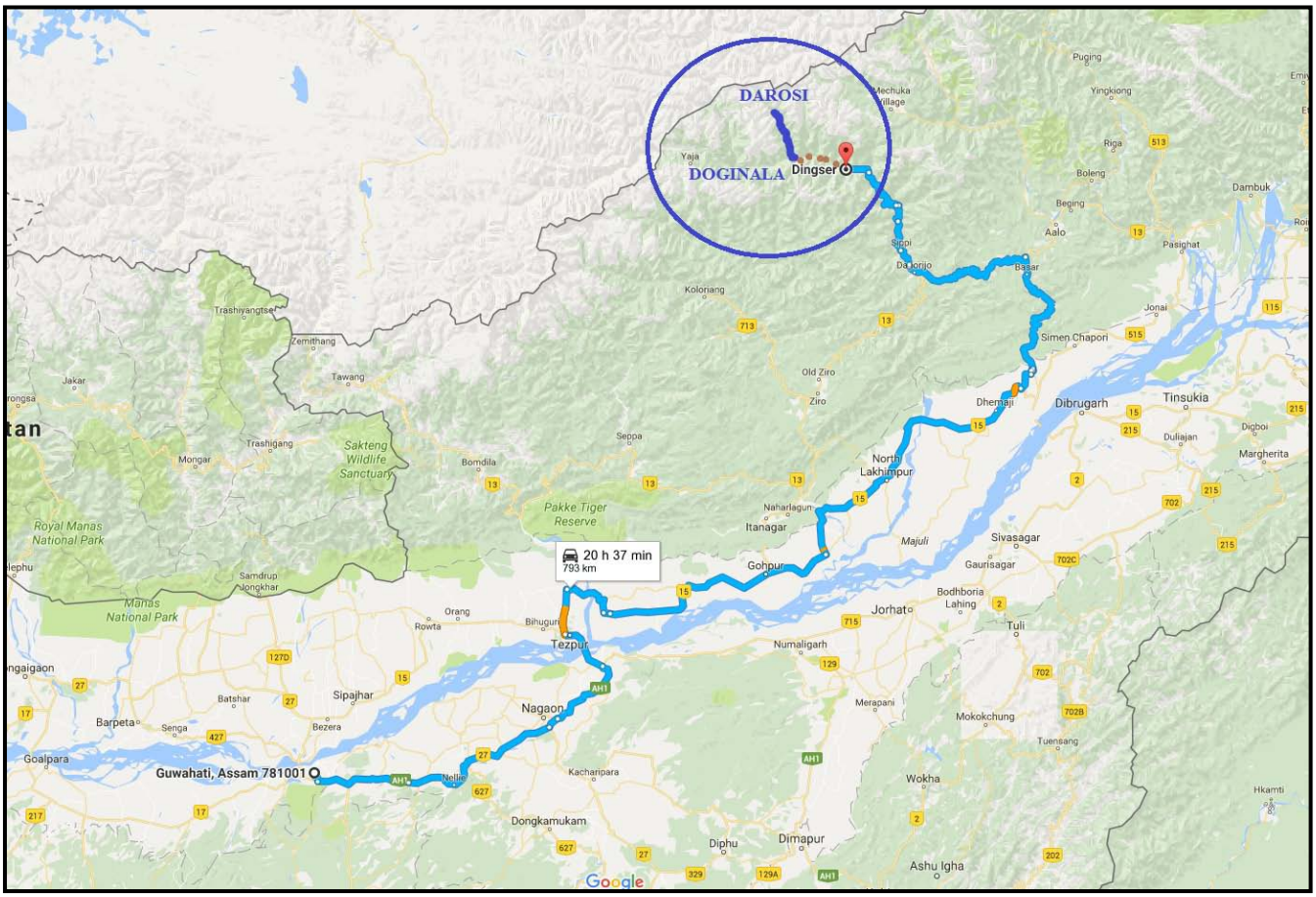
<table>
<tr><th>Description</th><th></th><th>Proposed</th></tr>
<tr><td>Terrain</td><td>:</td><td>Mountainous</td></tr>
<tr><td>Length provided by ITBP</td><td>:</td><td>50.00 Km</td></tr>
<tr><td>Designed Length</td><td></td><td>35.26 Km</td></tr>
<tr><td>Alignment</td><td>:</td><td>New Alignment</td></tr>
<tr><td>Design Speed</td><td>:</td><td>30 kmph</td></tr>
<tr><td>Cross – Section</td><td>:</td><td>Flexible Pavement
Single-lane (Class 9 road)
0.6 m Drain + 1.25 m Shoulder + 3.75 m C/W + 1.25 m Shoulder + 0.6 m Extra Widening (On Curve Portion Only)
<table>
<tr><th>SN</th><th>From</th><th>To</th><th>Length (km)</th></tr>
<tr><td>1</td><td>0</td><td>35.26</td><td>35.26</td></tr>
<tr><td></td><td></td><td>Total</td><td>35.26</td></tr>
</table></td></tr>
<tr><td>CBR considered</td><td>:</td><td>10%</td></tr>
<tr><td>Traffic</td><td>:</td><td>NIL</td></tr>
<tr><td>Pavement Design Life</td><td>:</td><td>15 Years, As per IRC:SP:48-1998, Clause 10.6, Sub Clause 10.6.1</td></tr>
<tr><td>Design MSA</td><td>:</td><td>MSA – 5</td></tr>
<tr><td>Pavement Crust Thickness for New construction</td><td>:</td><td>
<table>
<tr><th colspan="2">Flexible Pavement</th></tr>
<tr><td>Bituminous Concrete</td><td>40 mm</td></tr>
<tr><td>Dense Bituminous Concrete</td><td>60 mm</td></tr>
<tr><td>Crusher Run Macadam</td><td>200 mm</td></tr>
<tr><td>Granular Sub Base</td><td>200 mm</td></tr>
<tr><td>Total</td><td>500 mm</td></tr>
</table></td></tr>
<tr><td>Hume Pipe Culvert</td><td>:</td><td>HPC (1 X 1200) : 35 No’s</td></tr>
<tr><td>Slab Culverts</td><td>:</td><td>Slab Culvert (1x3 m) :107</td></tr>
<tr><td>Bridge</td><td>:</td><td>Nil</td></tr>
<tr><td>ROW</td><td>:</td><td>Design has been done by considering ROW width of 18.00 m</td></tr>
</table>

INTRODUCTION

General

Route Plan

From	To	Distance	Approx Time for Journey	Mode of Vehicle
Guwahati	Itanagar	380 Km	8 Hrs	By Road
Itanagar	Sippi	282 Km	9 Hrs	By Road
Sippi	Dingser	98 Km	6 Hrs	By Road With 4 wheel drive
Dingser	Doginala	8 Km	2 Hrs	By Kutcha Track With 4 wheel drive
	Total	**768 Km**		



The Project Road Doginala – Gau - Darosi Road starts at Doginala & terminates at Darosi. The design length of proposed alignment is 35.26 km. The project road falls in the district of **Upper Subansiri**.

DESIGN STANDARDS

Design Criteria

The design criteria for the Project Road have been adopted with the objective of construction of new road. The following guiding principles have been kept in view during evolving the highway designs:

Design Standards (Roads)

Terrain Classification

The project road under cover of this report lies wholly in mountainous terrain and the geometric standards relevant to mountainous terrain as per IRC: SP: 48-1998 and IRC: 86-1983 have been adopted.

Guiding Standards for Highways

The design of various elements of highways is governed by the provisions of the following IRC Codes / Guidelines / Manual.

- IRC: SP: 48-1998 - Guidelines for Hill Road Manual
- IRC: 37-2012 – Guidelines for the Design of Flexible Pavement.
- IRC: 38-1998 - Guidelines for Design of Horizontal Curves for Highways and Design Tables
- IRC:66-1976 - Recommended Practice for Sight Distance in Rural Highways
- IRC:67-2012 - Code of Practice for Road Signs (I Revision)
- IRC: 73-1980 - Geometric Design Standards for Rural (Non-Urban) Highways.
- IRC: 86-1983 - Geometric Design Standards for Urban Roads in Plains.
- IRC:SP:23-1983 - Vertical curves for Highways
- IRC:SP:44-1996 - Highways Safety Code
- IRC:SP:19-2001- Manual for Survey, Investigation and Preparation of Road Projects
- Manual for Safety in Road Design

Design Speed

Design speed depends on the function of the road as also the terrain conditions. It is the basic parameter which determines all other geometric design features. Considering the practical problems associated with Land acquisition and resettlement, the ruling and minimum design speed have been adopted at a lower value as shown below. This has been done in line with the stipulations in IRC: SP: 48-1998.

The design speed shall be as under depending on site condition and other considerations:

	Ruling	**Minimum**
Mountainous Terrain	30 km/hr	25 km/hr
Steep Terrain	25 km/hr	20 km/hr

If changes in the design speed appear unavoidable, gradual changes has been introduced by providing successive sections of increasing / decreasing design speeds so that road users become progressively conditioned to such changes.

Cross Sectional Elements

The guidelines based on IRC: SP: 48-1998 relevant to mountainous/steep terrain have been followed to finalize various elements of roadway as detailed hereinafter.

Embankment side slope (Hill side) should normally be 1 (H): 1(V) and varying up to 1/8 (H): 1 (V) depending upon the class of rock and stability of side slope. However, in case of Hard Rock cut may vary from 80^0-90^0 to horizontal. Carriageway shall have cross-slope of 2.00%

The shoulders shall have a slope of 2.5%.in super elevated sections the shoulders will have same cross fall as that of the Pavement- The shoulders on high side of the super elevated portion shall be provided with reverse slope from the super elevated carriageway portion.

Horizontal Alignment

Uniformity of design standards is one of the essential requirements of any road alignment. In a given section, there must be consistent application of design criteria to avoid creation of unexpected situations for the drivers. As a general rule, the horizontal alignment should be fluent and blend well with the surrounding topography.

- **Horizontal Curves**

  The horizontal curves for this project road have designed in accordance with the requirements as stipulated in IRC: 38-1988. Horizontal curves will normally consist of a circular curve flanked by spiral transition curves at both ends.

  The transition curves have been facilitate gradual application of super-elevation and ensure smooth entry of vehicles from straight to the circular curve without causing any discomfort to the driver.

- **Super elevation**

  Super elevation provided on horizontal curves based on the following formula:

  $e = V^2 / 225R$

  Where, e = super elevation

  V = speed (km/hr.)

  R = radius (meter)

  Super elevation as per IRC: SP: 48-1998, Clause 6.8.2 and Sub clause 6.8.2.2 and as obtained from the above expression is limited to the following values.

a.	In snow bound areas	7%
b.	In hilly areas not bound by snow	10%

- **Radius of Horizontal Curves**

The radii of horizontal curves are calculated from the following formula:

$$R = V^2 / 127(e + f)$$

Where, V = vehicle speed (km/hr.)

e = super elevation ratio (meter / meter)

f = coefficient of side friction between vehicle tyres and the pavement (taken as 0.15)

R = radius (meters).

- **Transition Curves**

Transition curves are necessary for vehicles to progress smoothly from a straight alignment into a circular curve or between curves of different radius. The transition curve also facilitates a gradual application of the super elevation and any widening of the carriageway which may be required for the horizontal curves. Spiral curves are used for this purpose.

The length of the transition curve is determined from the following two considerations, i.e. i) rate of change of centrifugal acceleration, ii) rate of change of super elevation- The larger of the two values is adopted for design:

$$Ls = \frac{0.0215\, V^3}{CR}$$

Where, Ls = length of transition in meters

V = speed in km/hr

R = radius of circular curve in meters

C = 7V-(maximum of 0.8 & minimum of 0.5)

- **Widening of Carriageway on Curves**

At sharp horizontal curves, it is necessary to widen the carriageway to Provide for safe Passage of vehicles. The extra width of 0.6 m has been provided at horizontal curves.

Setback Distance at Horizontal Curves

Requisite sight distance is to be available across the inside of horizontal curves- The set-back distance will be calculated from the following equation:

m = R- (R-n) Cos ø

Where, ø= S/ 2(r-n) radians

m = minimum set-back distance to sight obstruction in metres

R = radius at center line of road in meters

n = distance between the center line of the road and the center line of the inside lane in meters.

S = Sight distance in meters.

Where horizontal and summit vertical curves overlap, the design is Provide for required sight distance both in vertical direction along the road and in the horizontal direction on the inside of the curve.

Vertical Alignment

- **Gradient**

The vertical alignment is provided with a smooth longitudinal profile consistent with the terrain through which the road passes. Gradients up to the "ruling gradient is used as far as Possible in the design. Grade steeper than the "ruling gradient" is used for a length "as short as Possible".

- **Vertical Curve**

Vertical curves are introduced for smooth transition at grade changes. For satisfactory appearance, the minimum length of vertical curves is provided based on design speed as mentioned in IRC: 73 & IRC: SP: 23.

- **Summit curves**

The length of summit curve is governed by the choice of sight distance. The length of summit curve is calculated for Intermediate sight distance unless there are site constraints when a safe stopping sight distance is provided

For safe stopping sight distance

Case (I) when L>S

$$L = NS2/ 4.4$$

Where, N = Deviation angle Le. Algebraic difference between two grades.

L = Length of parabolic vertical curve in meters

S= Sight distance in meters

Case (ii) when L<S

$$L = 2S - 4.4/N$$

For Intermediate sight distance

Case (i) when L>S

$$L = NS^2 / 9.6$$

Case (ii) when L<S

$$L = 2S - 9.6/N$$

- **Valley Curves**

Valley curves are designed for headlight sight distance.

Case (I) when L>S

$$I = \frac{NS^2}{1.50+0.035\ S}$$

Case (ii) when L<S

$$L = \frac{2S - 1.50 + 0.035S}{N}$$

Sight Distance

On consideration of driver's perception time & braking time required to control their vehicles to avoid unwarranted accidents before meeting a stationary object in his path, proper sight distance will be required.

The various curves are designed corresponding to minimum Safe Stopping Sight Distance according to adopted Design Speed as detailed below:

Stopping Slight Distance

Speed in Km/Hr.	Safe Stopping Slight Distance (meters)	Intermediate Sight Distance (meters)
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

Pavement Design

General

- The pavement design activities include construction of single lane carriageway.

Design of Flexible Type Pavement Overlay

- Not Applicable as there is no existing track available.

Design of Pavement for New Construction

- Design of Flexible Pavement
- Design of flexible pavement for new construction is done following "Guidelines for the

Design of Flexible Pavement (Second Revision), IRC: 37-2012" with the latest MoRT&H circulars. The design process includes:

Homogeneous Sections

- Homogeneous sections for new construction have been adopted based on the type of founding strata for embankment, sub-grade, height of embankment and traffic.
- CBR of sub-grade / Module of Resilience of road bed soil.

- **Design Life**
  - The design life for flexible pavement is 15 years according to IRC: SP: 48-1998. Clause 10.6.

- **Design Traffic**
  - As this alignment is entirely new alignment and there is only a foot track is available, we have adopted a value of 5 MSA.
  - **Thickness of pavement layer**
  - The flexible pavement is designed as per IRC: 37-2012 for 5 MSA traffic and 10 CBR value.

Miscellaneous Items

Traffic Signs

To ensure safe and efficient flow of traffic in the high speed project corridor, traffic must be regulated through a system guidance and control systems. Accordingly traffic signs, of retro- reflective types, as per IRC: 67:2012 is provided as follows:-

- Mandatory/Regulating signs (violation of which is legal offence) e.g. stop signs, speed limits etc.
- Warning / Cautionary signs to warn the road users of existence of certain restrictions / hazardous conditions.
- Informatory signs e.g. distance information boards directions signs, route number etc.

Kilometer Stones

Kilometer stones are provided along the road on the left side as follows:-

i. 5th kilometer stones as per IRC: 8-1980.

ii. Kilometer stone as per IRC: 8-1980.

iii. Hectometer stone as per IRC: 26-1967.

Delineator

Road delineators are provided as visual aids for safety at night as per IRC 79-1981 for the horizontal curves.

Traffic Safety Measures

RCC Retaining walls are provided along the edges of formation on unstable slopes on hill side and valley side and sharp horizontal curves to prevent vehicles accidentally leaving the highway as per relevant IRC specification.

Cost Estimate and Specification

The detailed estimated cost for the road section has been prepared on estimation of quantities from the detailed design and drawings. The rates for the individual items have been adopted based on the prevailing market rates.

Details of Machineries required for mechanized construction are as below.

Sl. No.	Description	Doginala – Gau – Darosi
1	Dozer D-50-A 15	3
2	Dozer D-80-A 12	3
3	Motor Grader 3.35 meter blade	4
4	Hydraulic Excavator of 1 cum bucket	10
5	Front end loader 1 cum bucket capacity	10
6	HYVA/ AMW Tipper-5 cum	20
7	Vibratory Roller 8 tonne	5
8	Smooth Wheeled Roller 8 tonne	5
9	WMM Paver finisher	2
10	Water Tanker	15
11	Tractor	2
12	Air Compressor	2
13	Wet Mix Plant 60 TPH	1
14	Mechanical Broom Hydraulic	4
15	Bitumen Pressure Distributor	2
16	Hot mix Plant - 40 to 60 TPH capacity	1
17	Paver Finisher Hydrostatic with sensor control	1
18	Hydraulic Chip Spreader	2
19	Tandem Road Roller	2
20	Pneumatic Road Roller	2
21	Pot-Hole Repair Machine	2
22	Bitumen Boiler Oil Fired	2
23	GSB Plant 50 cum	1
24	Stone crusher 100 TPH adequate capacity generator	As per requirement
25	Concrete Bucket - 1 cum capacity	6
26	Concrete Mixer	2
27	Generator	
	(a) 250 KVA	2
	(b) 63 KVA	10
	© 25 KVA	10
	(d) 33 KVA	2
28	Total Station, Auto Level & Differential GPS	As per requirement
29	Any Other if required i.e., Blasting Equipment, compressor	4
30	Integrated Batching Plant 30Cum/Hr	1

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- The project road Doginala – Gau – Darosi falls in the state of Arunachal Pradesh.
- The terrain is mountainous and has steep gradients.
- The proposed Length of Project road is 35.26 km.
- The project has been proposed for implementation in single construction package.
- It is proposed that duration for completion of whole project shall be 5 years including non working period.

Recommendations

- The design Length of Project road is 35.26 km.
- The Project road is proposed as Single lane with shoulder, drain, extra widening (3.75m + 2 x 1.25m + 0.6 m + 0.6m)
- Proposed ROW is taken 18.00 m areas as per provision in IRC: SP: 48-1998.
- The Pavement of Project road is proposed only as **flexible pavement**.
- The Crust is designed on basis of 5 MSA and 10% CBR.
  Crust is -

BC	40 mm
DBM	60 mm
CRM	200 mm
GSB	200 mm

- The horizontal & vertical improvements are proposed as per site requirements.

The alignment protection measures including Breast walls, crash barriers etc and cross drainage works have been considered as per present site condition. After formation cutting, some technical improvements may be required. These shall be incorporated at that stage.

Traffic Survey Report

Introduction

Traffic Surveyors understand the appreciation of existing traffic and travel characteristics is vastly important to boost wide-ranging traffic and transportation plan.

With extreme years of experience in survey services viz. Traffic survey, Pedestrian count, Vehicle parking, Origin-destination survey and associated services, Traffic Surveyors brings a wealth of knowledge and experience to any proposed projects.

Purpose of the Report

The purpose of this report is to:

- Identify existing traffic data
- Describe new data collection requirements
- Presents the findings of data collection undertaken
- Determine if the data collection is fit for use

Overview

The proposed alignment is a link between Doginala - Darosi in the state of Arunachal Pradesh. The total length of the proposed alignment is 41.21 km. As the entire proposed alignment is a new alignment, there is no traffic survey have been conducted on the same.

Inventory Report

Road Name : Doginala – Gau - Darosi

Section : From km 0+000 To 35+260 | **District : Upper Subansiri**

Chainage		Type of Terrain	Land Use	Name of village/ town	Right of Way (m)	Road way Width (m)	Carriageway			Shoulders		Average Height of Emabankment or depth of cutting (m)	Road Side Drainage		Service Road, if any	Details of Cross Roads			Remarks
Km	Km						Type	Width (m)	Condition	Type	Width (m)		Exists (F/NF)	Does not exist		Location	Destination	C/W(m)	
0+000	35+260	Hilly	Forest	-	-	-	-			-	-	-	-	-	-	-	-	-	Foot Track

INVENTORY AND CONDITION SURVEY FOR BRIDGES

Road Name : Doginala – Gau - Darosi

Section : From km 0+000 To 35+260

District : Upper Subansiri

S. No.	Bridge No.	Location (Km)	Name of river bridge	Year of Construction	Type of Structure			Type of bearing	Type of expansion joints	Type of wearing coat	Whether high level yes/no	Total length (m)	Length Face to face of Drit wall (m)	Span or viaduct Arrangement		Avg. vertical clearance (below bottom of girder/ soffit)	Width of carriageway b/w Kerbs (m)	Total outer Width of Bridge (m)	Width of foot path (m)	Present condition of										Protection work		Whether waterway adequate (yes/ no)	HFL	LWL	Nature of bed	Remarks
					Superstructure	Substructure	Foundation							No. of Spans	Length of Spans (m)					Bearing	Expansion joints	Wearing coat	Parapet/ railing/ crash	Foundations	Abutments	Piers	Superstructure	Approach slab	Guide bunds	Other protective works	Other items (Specify)	Bed	Approaches					

NO EXISTING BRIDGE AVAILABLE ON SITE

INVENTORY AND CONDITION SURVEY FOR CULVERTS

Road Name : Doginala – Gau - Darosi

Section : From km 0+000 To 35+260

District : Upper Subansiri

Sl. No.	Chainage	Type of structures	Thickness of Slab (m)	Span Arrangement and Total Vent way (No. X Length) (m)	Width of Culvert (m)		Length of culvert (m)	Condition of various features of Culvert					Height above Bed Level		Whether waterway adequate (Yes/No)	Remarks
					Total (m)	Carriageway (m)		Slab/Pipe/Box/Arch	Head Wall	Wing Wall	Return Wall	Parapet/Handrail	U/S Side (m)	D/S Side (m)		
NO EXISTING CULVERT AVAILABLE ON SITE																

Material Report

MATERIAL INVESTIGATION AND ANALYSIS

Material Investigations

Introduction

The objective of material investigations is to identify the source of natural materials like soil, sand, stone, cement, steel etc. near and along the alignment of the project road as required for the construction of the embankment and sub grade under the pavement and as also the source of aggregates/stones, sand, Steel and Cement for the construction of road pavement, embankment, bridges, culverts and other structures.

Source of Materials

Soil Borrow Sources

There is no provision of Embankment as the entire alignment is to be constructed by cutting of hills. Only at some patches, excavated material shall be used for minor filling.

Stone Quarry

The stone available in the nearby areas to the project alignment including the excavated material is not found suitable for crust as well as RRM works due to its lesser strength. Therefore, it is proposed to obtain the stone from the river beds, which are available at an average lead of 50 km and the same may be used in the permanent works. Further, no existing crushers are available at / near the alignment, hence the Contractor has to install its own crusher for production of aggregate.

Crust Composition

As per clause no 1.5 and 2.1 of IRC: 37-2012, there is clearly mentioned that the local environment and past pavement performance in the respective region must be considered, while selecting a pavement thickness. Hence, as the proposed road mostly falls under snow prone area, the wearing course should be of higher thickness. Further, due to unavailability of binder material, WMM or WBM can't be feasible. So based on the surrounding circumstances and availability of required construction material following thickness of crust has been adopted.

SN	Section	Adopted MSA	Adopted CBR (%)	Pavement Composition (mm)			
				BC	DBM	CRM	GSB
1	Doginala- Gau - Darosi	5	10%	40	60	200	200

Sand

The sand for construction purpose may be extracted from the river bed near to alignment however; royalty for the same is to be paid to the State Government.

Coarse Aggregate

The Proposed Alignment is Road assessed 16.88% Hard Rock 83.12% all kind of soil (include Ordinary Rock) as per quantity calculation sheet. Hence, Good quality aggregate of various sizes is available. However, Crusher

needs to be installed.

Within 10Km radius of the project, ample quantity of hard rock is available where crusher may be installed and aggregate shall be transported to site. However, the royalty for aggregate has to be borne by the Contractor.

Cement

Cement to be used in the construction work shall be any of the following types with the prior approval of the Engineer:

- Ordinary Portland cement, 33 Grade, conforming to IS: 269
- Rapid Hardening Portland Cement, conforming to IS: 8041
- Ordinary Portland cement, 43 Grade, conforming to IS: 8112
- Ordinary Portland cement, 53 Grade, conforming to IS: 12269
- Sulphate Resistance Cement, Conforming to IS: 12330

The chloride content in cement shall in no case exceed 0.05 percent by mass of cement. Also, total sulphur content calculated as sulphuric anhydride (SO3) shall in no case exceed 2.5 percent and 3.0 percent when tri-calcium aluminates percent by mass is up to 5 or greater than 5 respectively.

The type of cement to be used in construction works shall be decided based on its 28 days cube strength only and no specific cement may be recommended for use.

The cement may be procured from Guwahati where the plant of Raksha and Surya Gold Cement are available; however some locally available cement like Dalmiya Bharat Cement, Purbanchal Cement, Star cement may also be procured. The average lead upto project site shall be approximate 849 km.

Steel

For plain and reinforced concrete (PCC and RCC) or pre-stressed concrete (PSC) works, the reinforcement/un-tensioned steel as the case may be shall consists of the following grades of reinforcing bars as shown in following table**:**

Grade / Designation	***Bar type***	***Characteristic strength (MPa)***	***Elasticity Modulus (GPa)***
Fe 500 D	IS: 1786 Thermo Mechanically Treated (TMT)	500	200

There is no steel plant within the Arunachal Pradesh state boundary except for some local manufacturers, whose quality standards are to be verified as they are producing the re-rolled steel and not from Billets / iron ore. We have considered that the steel from approved sources shall be bought from the SAIL in Guwahati district. The approximate lead from Guwahati to site shall be approximate 849 Km.

Bitumen

Bitumen can be procured from IOCL refinery at Baruni whose approximate lead is 1630 km.

Classification of Soil

Chainage		Type of Soil
From	To	
0	2800	All kind of Soil
2800	3200	Hard Rock
3200	4800	Ordinary Rock
4800	5100	Hard Rock
5100	8400	All kind of Soil
8400	9100	Hard Rock
9100	10500	All kind of Soil
10500	10900	Hard Rock
10900	14200	Ordinary Rock
14200	18600	All kind of Soil
18600	19100	Hard Rock
19100	21000	Ordinary Rock
21000	24600	All kind of Soil
24600	24800	Hard Rock
24800	28100	All kind of Soil
28100	29300	Ordinary Rock
29300	33800	All kind of Soil
33800	34600	Hard Rock
34600	35240	Ordinary Rock

Regarding the classification of soil, it is mainly with the visual inspection by an expert material engineer at the site and supported with CBR values.

It is also pertinent to mention that the classification of soil as well as CBR values are of OGL and has no relevancy with the FRL as the proposed FRL is about 5 - 20 meter below the OGL. The firm classification and CBR values can only be evaluated after cutting upto formation level.

Design Standards

DESIGN OF ROAD

GENERAL

The present design report is comprised of a variety of elements joined together to create a facility that serves the traffic in a safe and efficient manner, consistent with the facility's intended function. Each alignment element complements others to produce a consistent, safe, and efficient design. Several principal elements of design are taken into consideration. These include sight distance, super-elevation, grades, horizontal and vertical alignments, and other elements of geometric design.

Design Report deliberates on roadwork elements designed, which include following essential items of road work:

1. Geometrics
   - Horizontal alignment
   - Vertical profile
   - Cross sections
2. Intersections and other facilities
3. Road safety features, etc.

Design Elements

Terrain

Terrain classification as per IRC: SP: 48-1998 i.e., Geometric Design standard of hill road are given hereunder.

Plain: Terrain where percent cross slope of the country is generally less than 10.
Rolling: Terrain with percent cross slope ranging from 10 to 25.
Mountainous: Terrain with percent cross slope ranging from 25 to 60.
Steep: Terrain where percent cross slope of the country is greater than 60.

Design Speed

The proposed design speed is at maximum speed of 30 Kmph.

Radii of Horizontal curves

According to IRC, minimum radius of horizontal curve is determined based on a value of 0.07 for super-elevation rate, e and 0.15 for side friction. While the maximum "e value" is an acceptable practice, the adoption of a constant rate of 0.15 for side friction for all design speeds is questionable. The international practice in this regard is to adopt friction factor varying with speed with lower factors for higher speeds. The effect of higher friction factor at higher speeds is reduction in radius of curves. As the prescribed design speeds are somewhat on the high side, adoption of friction factor of 0.15 serves as a compensating effect and accordingly no change to the IRC Policy has been proposed.

For project roads in hilly terrain, and should have a gradient of 1:20 to 1:25 to develop self cleaning velocity to disperse floating debris conveniently. A Summit vertical curve has been designed generally for stopping sight and the Valley curve provide for head light sight distance equal to stopping distance as the minimum.

Sight distance for vertical curves

Sight distance standards of IRC for safe stopping and overtaking are acceptable and were adopted. Stopping sight distance has been provided in the design for Vertical Curves.

Super-elevation

The Maximum Super-elevation for the project road is restricted to 7% and calculations were based on the assumption that the entire centrifugal force generated at a curve at $2/3^{rd}$ of the design speed would be balanced by super elevation and higher speeds by a combination of super-elevation and side friction.

Where transition curve is not provided, the super elevation runoff length is $2/3^{rd}$ on straight $1/3^{rd}$ on curve.

Cross Sectional Features:

(a) Number of lanes

Single-lane pavement width is suggested as 3.75m in IRC: SP: 48-1998.

(b) Shoulder

In a roadway cross section shoulder is an essential feature. Shoulders provide recovery area for errant vehicles; a refuge for stopped or disabled vehicles; and access for emergency and maintenance vehicles. Shoulders can also provide an opportunity to improve sight distance through large cut sections.

According to IRC: SP: 48-1998 design standards, a shoulder of 1.25 m.

(c) Side slope

Embankment side slope (Hill side) should normally be 1 (H): 1(V) and varying up to 1/8 (H): 1 (V) depending upon the class of rock and stability of side slope. However, in case of Hard Rock cut may vary from 80^0-90^0 to horizontal.

(d) ROW

Proposed ROW for construction of new road is taken maximum width of 18.00 m throughout the stretch as per provision in IRC: SP: 48- 1998.

(e) Cross slope

As per IRC: SP 48-1998 design standards recommendation the camber of 2.5% for the main carriageway and 3.0% for shoulders has been proposed for the project.

Horizontal Alignment

Project Road traverses through hilly & steep terrain. The proposed alignment improvement design is based on various parameters. The design principles for alignment selection have been evolved based on discussions with the expertise Highway Engineers, Bridge Design Specialists, Environmentalist, Transport and other key personnel. The selection of the alignment is broadly based on the following criteria;

- Technical soundness and economic viability.
- Least social and environmental adverse impact.
- Least displacements and loss of public property.
- Avoiding adverse impact to water bodies and other environmental features.
- Locations of required causeways.

Present Alignment

There is no existing alignment. The proposed stretch is entirely a new alignment that is to be constructed.

Alignment Design

Powerful civil engineering highway design software MX-Road has been to carry out horizontal and vertical alignment design. The survey data was presented in AutoCAD drawing format with each entity represented in 3D (X, Y, Z) co-ordinate system. The detailed design was carried out on the basis of design standards adopted through following steps:

- Importing survey data into MX-Road in AutoCAD.
  Develop Digital Terrain Model (DTM).
- Developing triangulation model and generating contour plans for the existing ground/road surface.
- Designing horizontal alignment along the centerline of proposed median.
- Designing vertical alignment with triangulation model simulating the existing ground/road surface.
- Designing carriageways and shoulders for the entire alignment.
- Designing super elevation for the road surface generated.
- Calculating earthwork, subgrade, pavement and profile quantities by superimposing design surface over existing surface.
- Generating reports for horizontal and vertical alignment using report option. The types of reports generated are discussed below.

Alignment Reports

The detailed reports, generated for entire alignment using report option of MXROAD design software.

Horizontal Alignment Report

This was generated to give details of individual elements constituting the entire horizontal alignment along the centerline of proposed carriageway. This includes details of co-ordinates, chainage and length of individual elements. Proper drainage is also planned at the curve locations keeping in view of super elevation design.

The detailed Horizontal Design Report showing all the elements including curve length, transition length, Radius of the curve, design speed and super elevation etc. and other necessary details with respect to proposed design alignment have been given in the **Road Drawings Volume.**

Vertical Profile Report

The vertical curves have a minimum sight distance generally 45 m and the carriageway profile has been designed with super elevation up to 5% depending upon radii of horizontal curves in different sections but at very few locations it is up to 7% also. The vertical profile of the new carriageway has generally been designed as per the improvement options found from the study of existing pavement conditions. In few sections of the project road due to geometric improvements in terms of gradient it is proposed to reconstruct the existing carriageway to the appropriate new carriageway level.

This report gives details of individual elements constituting the entire vertical alignment. The report includes gradients, vertical curve details including levels and chainage of obligatory points.

The detailed Vertical profile Report showing all the elements including curve length, grades, levels details etc. with respect to proposed design profile has been provided in **Road Drawings Volume.**

Drainage

Introduction

Road drainage includes the collection and diversion of surface and subsurface water. In order to ensure proper drainage of the road surface and the pavement layers different drainage arrangements have been considered for the project. The drainage system for the project road has been made in accordance with IRC: SP: 42-1994 “Guidelines on Road Drainage”.

To drain off water across the carriageway and shoulders it is necessary to provide a combination of longitudinal gradient and cross slope. Minimum cross slope to ensure runoff without risk of aquaplaning is generally assumed as per IRC: SP: 48-1998.

Drainage of Pavement Layers

To ensure that water does not accumulate in the pavement layers, these must be drained. The lowest GSB layer will therefore be carried through to the embankment slope under the shoulders.

Drain Channels

Surface water drain off is to remove the water from carriageway, and shoulders by providing sufficient cross slope. The cross slope has been fixed in order to achieve a balance between effective runoff without compromising the comfort and safety of the road users.

Sub-Surface Drainage

The sub-soil drainage represents the drainage of the water trapped in the subgrade, which may be due to percolation or infiltration of water from the pavement, and shoulder, and also from the adjoining standing water through capillary action. It is important to drain off such water as it damages the road crust causing failure of the pavement by various reasons such as striping of bitumen, subgrade weakening etc.

The proper planning and provision of roadside drains and its effect on the overall cost of the project are minimal considering the overall benefits and pavement durability.

Detailed Design

During the detailed investigation and design of the road components, the requirement of the roadside drains has been assessed properly. The design of the roadside longitudinal drains has been done on the basis of the guidelines outlined in IRC SP: 42-1994. The cross sectional requirements of the drains with respect to hydraulic sufficiency, bed slope, drain types and construction techniques.

Road Safety Features

Safety measures are the project road. These are briefly explained in subsequent paragraphs.

(a) Safety of Vehicles

On account of increased vehicle speeds some protection for vehicles at curve locations, provision of visually conspicuous road features like carriageway edge markings, road signs, direction signs, etc become essential. Safety features for vehicles will include the following;

Road Furniture and Signs

Road furniture is provided for the proposed road includes traffic signs, road delineators, kilometer /hectometer stones, etc.

Road Signs

Road signs are one of the traffic aides to regulate, inform and guide traffic for safe movement on the road. These also provide information about the traffic discipline to be followed on the highway. Road signs for the project road have been provided under the following categories;

- Mandatory/Regulatory signs
- Cautionary/Warning signs
- Informatory signs

The Typical detail of Road Signs is shown in miscellaneous part of drawing volume.

Mandatory/Regulatory Signs

These include all signs, which give notice of special obligations, prohibitions or restrictions with which the road users must comply. The violations of these signs are a legal offence. Stop signs, speed limit signs; restriction ends signs, etc. fall under this category.

Cautionary/Warning Signs

These signs are used to warn road users of the existence of certain hazardous conditions either on or adjacent to the roadway, so that the motorists are cautious and take the desired action. Right hand/left hand curve signs.

Informatory Signs

These signs are used to guide road users along routes, inform them about destination and distance, identify points of geographical and historical interest and provide other information that will make the road travel easier, safe and pleasant. Advance direction signs, reassurance signs, etc. fall under this category.

These signs shall normally be placed at right angles to the line of travel of the approaching traffic. The locations, materials, posts, colour and sizes for the sizes for the signs shall be in accordance with IRC: 67-2001 “Code of Practice for Road Signs”. Details of typical road signs are shown in drawings volume.

Delineators

Reflective Delineators: Delineators are provided to guide the road users for the delineation of carriageway, sharp horizontal curves and steep gradients higher than 5%. Object markers are used to indicate hazards and obstructions within the vehicle flow path.

The design, materials and locations of the road delineators are conforming to the Recommended Practice for Road Delineators - IRC: 79 and relevant drawings.

They are basically driving aids and should not be regarded as substitutes for warning signs, road markings or barriers. Delineators have been provided for suitable curve locations having radius less than 1000m.

Kilometer Stones

(a) Kilometer Stones

Kilometer Stones will be provided at left side of the carriageways. These will be provided in accordance with IRC: 8-1980 “Type Design for Highway Kilometer Stones”. Typical details for Kilometer Stones and their fixing are included in drawing volume.

These are to be made of precast M-20 grade reinforced cement concrete, and lettering / numbering as per the respective IRC codes.

The Typical detail of Kilometer Stone is shown in miscellaneous part of drawing volume.

(b) Kilometer and 5th Kilometer Stones

Kilometer stone and 5^{th} Kilometer stones will be provided at left side of carriageway. These will be provided in accordance with IRC: 8-1980 "Type Design for Highway Kilometer Stones". Typical details for 5th Kilometer Stones and their fixing are included in drawing volume.

(c) 200 m Stones

200 m stones shall be provided in-between Kilometer stones on left side of carriageway. These will be fixed in accordance with IRC: 26-1967. Typical details for 200 m stones are included in drawing volume.

In addition, boundary stones at 200 m interval staggered on each side have been proposed as per the provision of IRC: 25-1967.

Side cutting and erosion Control (As per IRC: 56-2011)

a) Control of Erosion of Hill Slopes

Hill slopes are subject to erosion from flowing water leading to the foot of the hill slopes. The debris carried away by the flowing water may damage the slopes downhill and chock the streams. Surface erosion needs to be controlled else there is high probability that the erosion may extend deeper and wider that eventually endanger the stability of slopes.

There are certain methods which are described below to cater such effect on Stability of Slopes.

i. Asphalt mulch treatment.

The Asphalt mulch treatment is effective in controlling erosions of hill slopes by providing suitable turfing. The Asphaltic film gradually disintegrates and its place is taken by a carpet of green vegetation and deep rooted species of grass, clover etc. This method, if done just before the monsoons, the increased moisture content due to rains automatically helps in the growth of saplings.

ii. Slope Treatment by Jute/Coir netting.

The Jute/Coir netting are promising techniques for erosion control specially where problems is of surficial nature.

iii. Bally Benching

Bally benching is used for control of surface erosions on slides area as well as for arresting shallow movement of the top mantle of slide mass.

b) Rock slope protection

Hill slopes composed of rocks are prone to generate rock fall and rock slide hazards. It has been a common experience that the long after the construction has been completed, rock fall or slide incidence can occur.

A number of methods are available for the control of rock slope instability. Some of the methods are listed below.

i. **Shotcreting of slopes**

Shotcrete consists of cement mortar with aggregate upto 20 mm sizes, and is applied to the surface by an air jet. Thickness of layer deposited varies from 70 mm to 100 mm.

ii. **Grouting**

Grouting is used to improve weathered slopes from which rock or boulders may be falling.

iii. **Provision of rock collecting trenches**

iv. **Benching of slopes**

v. **Provision of rock fall fences, fixed or swinging type.**

By providing suitably placed benches or ditches that intersects the trajectory of the falling rocks, the roadway and other structures can be protected from the rock fall hazard.

vi. **Provision of protection sheds, tunnels or covered galleries**

vii. **Provision of rock bolts and anchors**

Rock blots and anchors are used to strengthen, reinforce or tie together unstable blocks or beds of rocks.

viii. **Covering the slopes with coir-netting or geogrids**

In this technique, the susceptible slope is covered with a geogrid mesh.

The above arrangements may be used in case of any slide/loose pocket which may be witnessed after start of excavation and preparation of formation. These methodologies are specialized jobs and cannot be evaluated for feasibility/cost at this stage. However, these are time tested and well known practices for such solutions.

The cost and design of these arrangements shall be submitted at construction stage after proper investigation of problem and discussion with service provider.