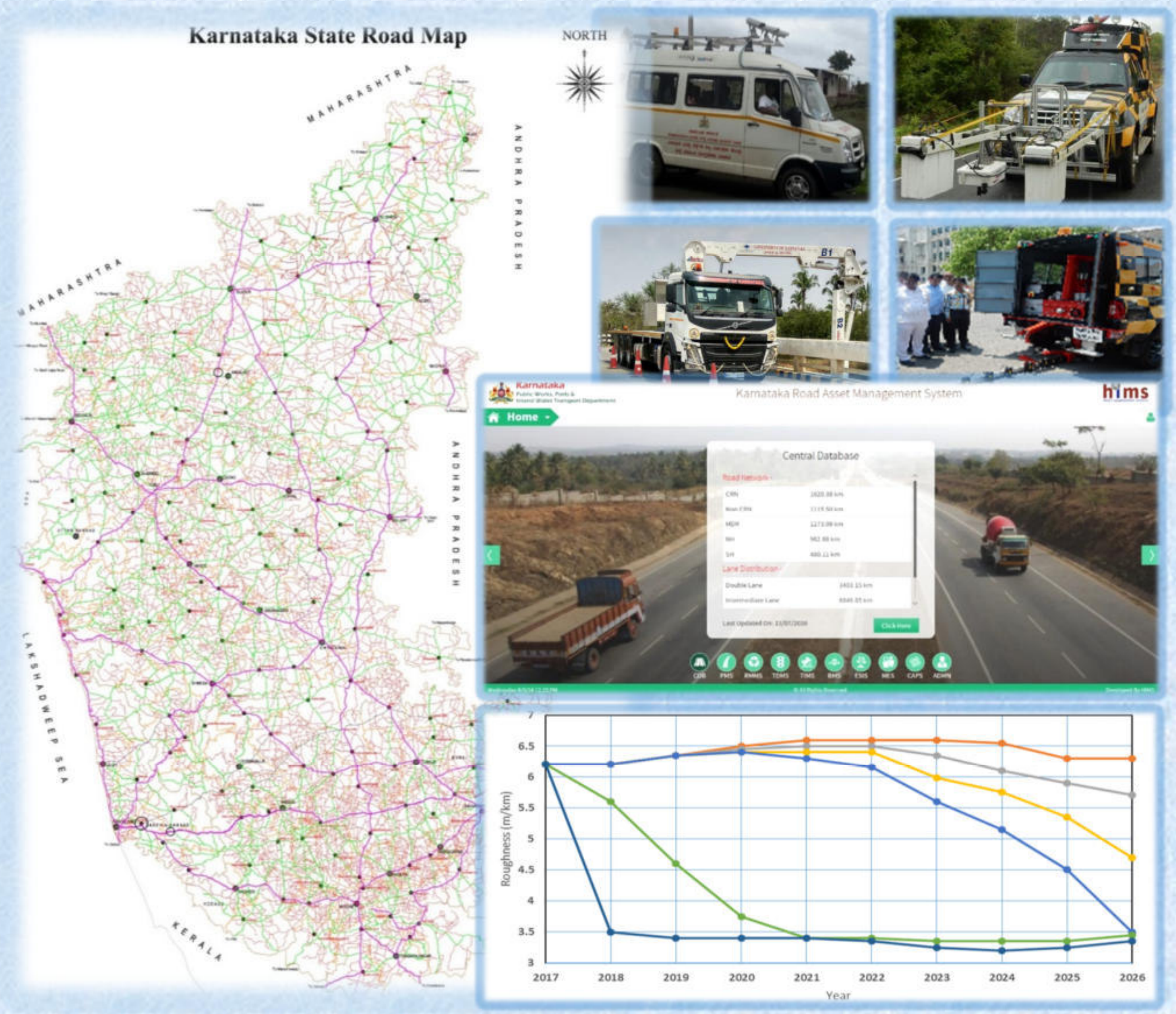
Government of Karnataka
Public Works Department

# Road Data Collection, Data Processing and Quality Assurance Procedures




## Planning and Road Asset Management Centre

Government of Karnataka

Public Works Department

# ROAD DATA COLLECTION PROCEDURES

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# ABBREVIATIONS

| | |
|---|---|
| CRN: | Core Road Network |
| DAD: | Digital Antenna Driver Controller |
| DGPS | Differential Geographic Positioning System |
| DMI: | Distance Measuring Instrument |
| FWD: | Falling Weight Deflectometer |
| GAGAN: | GPS Aided Geo Augmented Navigation |
| GPR: | Ground Penetrating Radar |
| GPS: | Geographical Positioning System |
| HRDMI: | High Resolution Distance Measuring Instrument |
| IRI: | International Roughness Index |
| LRMS: | Laser Rut Measurement System |
| LRP: | Location Referencing Point |
| MDR: | Major District Road |
| NH: | National Highways |
| PDB: | Power Distribution Box |
| PDOP: | Position Dilution Of Precision |
| PRAMC: | Planning and Road Asset Management Centre |
| PWD: | Public Works Department |
| RIS: | Road Information System |
| ROMDAS: | ROad Measurement Data Acquisition System |
| RoW: | Right of Way |
| SH: | State Highway |

# FOREWORD

The Government of Karnataka has received support from the Asian Development Bank (ADB) for the establishment of the Planning and Road Asset Management Centre (PRAMC) in the Public Works, Ports and Inland Water Transport Department (PWP&IWTD – PWD in short). The PRAMC functions include, Policy Development, Planning and Programming, Road Safety, Information Technology support and Training support across the whole of PWD by introducing state-of-the-art technologies. In order to perform its mandated functions PRAMC has identified and procured the advanced technological road data collection equipments as mentioned below

- ROad Measurement Data Acquisition System (ROMDAS)
- Falling Weight Deflectometer (FWD)
- Ground Penetrating Radar (GPR).

**ROad Measurement Data Acquisition System (ROMDAS):** ROMDAS is helpful in collecting road inventory, road condition, roughness and texture depth, rut, road alignments, along with video footages.

**Falling weight Deflectometer (FWD):** This equipment is used by civil engineers to evaluate the physical properties of pavement including elasticity moduli, the bearing capacity, and pavement deflection under standard axle load. FWD data is primarily used to assess the strengthening requirements of the existing pavement.

**Ground Penetrating Radar (GPR):** This is a geophysical equipment that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band of the radio spectrum, and detects the reflected signals from subsurface structures. Under PRAMC, GPR is used to assess the profiles of the underlying pavement layers and their thicknesses.

These equipments are mandated to be part of the regular data collection activities of PWD by following pre-established data collection procedures across the state. For this purpose, this document which gives insight of the utilities of the aforesaid equipment and provide guidelines about pre-survey, survey and post-survey activities, is being produced. However, it is to be noted that this document is not a replacement of the equipment's *User Manuals,* which are to be thoroughly referred for understanding the detailed concepts of equipments.

# 1. Introduction

## 1.1 Core Road Network (CRN)

Planning and Road Asset Management Centre (PRAMC) is responsible for Planning, Programming and monitoring the road maintenance works on the PWD road network. Within the overall road network of the state, the Government of Karnataka (GoK) has identified an initial Core Road Network (CRN) of approximately 25,000 km. This CRN comprises the mix of road links of National Highways (NH), State Highways (SH), Major District Roads (MDRs), which are considered most important for the economic and social development of the State. The composition of the road network CRN is as below

| Classification | Length(Km) |
|---|---|
| National Highways | 4,491 |
| State Highways | 18,470 |
| Major District Roads | 1,265 |
| **Total length** | **24,226** |

*Source: ADB-CDTA-1*

As a part of its mandated functions, PRAMC has been collecting several kinds of road data which is very much essential for determining the maintenance requirements of the CRN through state-of-the-art technologies.

## 1.2 Road Data Collection

Road data collection is critical to success of any road asset management, but too much inaccurate, unfriendly data is worse than having none at all. Hence, it is required to identify and collect the data which is actually used while preparing the annual maintenance / improvement programs.

During the inception stages PRAMC has identified the Road Data collection requirements along with the method of data collection. This data required to be collected, stored, managed, and analysed at regular intervals using the established method of data collection procedures. The overall road data collection requirements under PRAMC are broadly classified as

- Road Inventory and Condition Data;
- Pavement Strength;
- Pavement layers information;
- Video surveys.

Some of the above mentioned data is being collected by PWD as part of the regular data collection, however, the technologies and methods being followed are of outdated in nature and mostly manual in process. Hence, PRAMC has opted to procure advanced instruments for collecting the road data more accurately and with less human intervention. The following are the equipment procured by PRAMC for collecting disparate data

- Road Inventory ,Condition data and Video Surveys (**RO**ad **M**easurement **D**ata **A**cquisition **S**ystem –ROMDAS)
- Pavement Strength ( **F**alling **W**eight **D**eflectometer -FWD)
- Pavement Layers Details (**G**round **P**enetrating **R**adar -GPR).

## 1.3 Inventory and Condition Data

The Road Inventory and Pavement Condition Survey of CRN roads are carried out using **RO**ad **M**easurement **D**ata **A**cquisition **S**ystem (ROMDAS) Figure 1-1). ROMDAS comprises of the following components

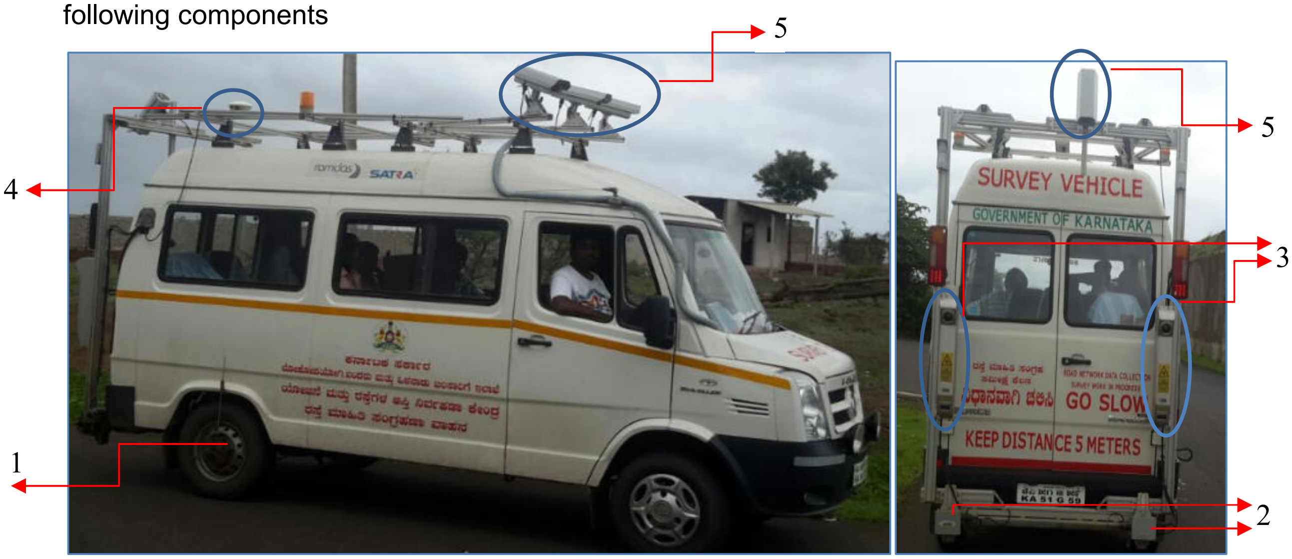



**Figure 1-1: ROMDAS Equipment**

1. Distance Measuring Instrument (DMI)
2. Laser Profilers
3. LRMS (Laser Rut Measurement System)
4. GPS receiver
5. Video Cameras ( Right of Way and Pavement)

Detailed elaborations of these equipments are given in the ensuing sections of this report.

## 1.4 Pavement Strength

Pavement strength is one of the most important parameters for determining the residual life of pavement and subsequently to estimate the strengthening requirements of the pavement (overlay requirements) to make the pavement functional till the design life of the pavement. Pavement strength is assessed by measuring pavement deflection under a pre-determined axle load. Earlier days the pavement deflections are measured by using Benkelman Beam Deflection (BBD) technique, however, this method is tedious and more susceptible to human errors. In order to overcome these issues, internationally recognised advanced equipments such as Falling Weight Deflectometer (FWD) came into existence. The FWD is a non-destructive equipment and measures the vertical deflection response of a surface to an impulse load using the automated methods. The FWD equipment comprises of an arrangement to simulate the dynamic load from truck on the pavement. The information collected using FWD can be used to determine (i) Bearing Capacity (ii) Layer Thicknesses (iii) Elasticity Moduli and (iv) Residual life (expected surface life).

Hence, PRAMC has procured an in-vehicle mounted FWD which is fixed on Tata Xenon 4x4 vehicle. The major components of FWD equipment are shown in Figure 1-2.

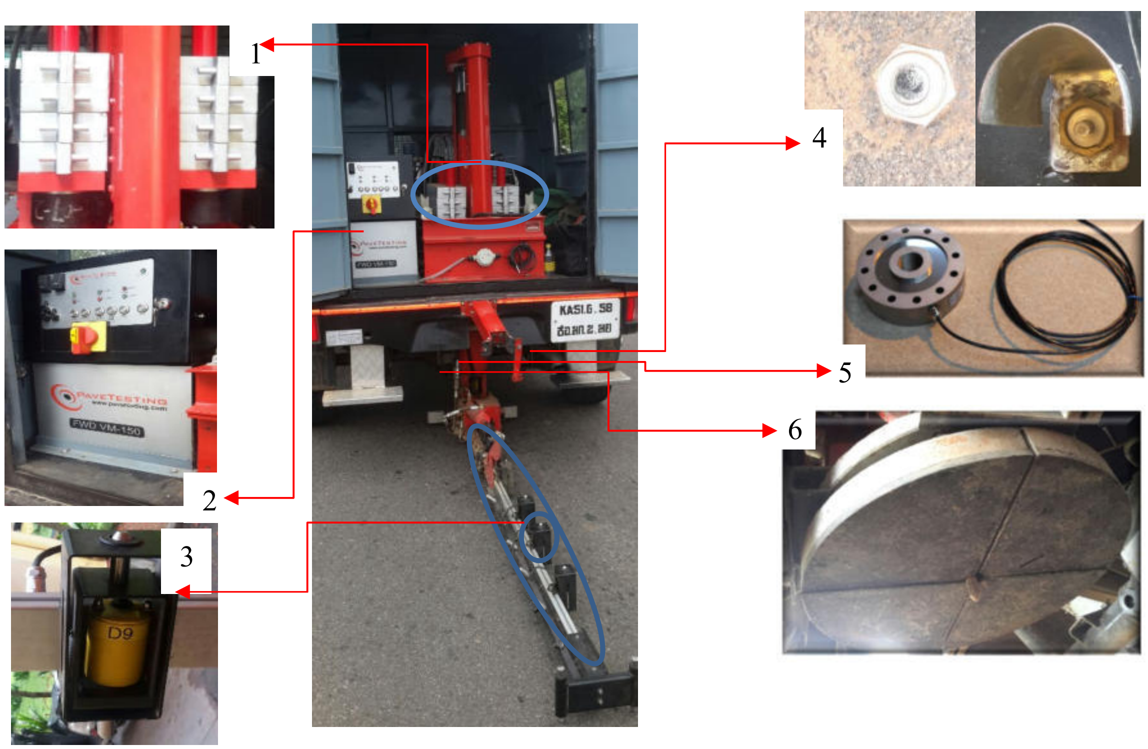



**Figure 1-2: In-vehicle mounted- FWD**

1. Weight Pack
2. Controller
3. Geophone Sensors (9Nos)
4. Temperature Sensors
5. Load Sensor / Cell

6. Load Plate

### 1.5 Pavement Layers Information

The existing pavement layers information is very critical in assessing the load bearing capacity of the pavement and also to identify the defects in the construction. The pavement layers information is used to be obtained by a destructive test of digging test / trail pits at select locations those are identified as per the homogeneity of the pavement condition.

In the recent past many technologies such as geophysical methods that uses radar pulses to image the subsurface came into existence. Initially these methods are not widely used in roads sector, however, after realising the benefits of these methods, their uses are extended to the road sector also and these methods are internationally accepted and proven successful in road sector.

PRAMC has procured Ground Penetrating Radar (GPR) for identification of the pavement layers and their thicknesses. GPR is a non-destructive method and uses electromagnetic radiation in the microwave band of the radio spectrum, and detects the reflected signals from subsurface structures, which can be used to identify the pavement layer profiles, thicknesses. This GPR equipment is mounted on the front side of vehicle in which FWD is in-vehicle mounted (Figure 1-3).



**Figure 1-3: GPR Arrangement**

The major components of the GPR equipment are

1. Horn Antennas (1 Ghz and 2 Ghz)
2. Dual Frequency Antenna (900/400 Mhz)
3. Digital Antenna Driver(DAD) Controller
4. Distance Measurement Instrument (DMI)
5. Global Positioning System(GPS)

## 1.6 Scope of this Document

The objective of this "Road Data Collection Procedures" document is to provide instructions to the data collection teams about various activities related to the field data collection. This document includes the following;

- General Guidelines of Data Collection;
- Road inventory and condition data collection- ROMDAS;
- Pavement strength data collection- FWD;
- Pavement composition data collection- GPR;

## 1.7 General

### *1.7.1 Roads and Links*

Road identification information is stored by PWD in the existing Road Information System (RIS) database. In RIS, the entire road network of the Karnataka has been broken down at the Taluk level and the road section between the taluk boundaries is named as Road. These roads of each taluk are further broken down into smaller road sections called links.

In RIS each road and link are given a unique six character identifier on the basis of Taluk. For example roads in Kolar Taluk are designated KOLXXX where KOL is the Taluk identification and XXX is a unique 3 digit road number. These Road IDs and Links IDs forms as a base to identify the roads, links for data collection activities.

### *1.7.2 Data Collection Plan*

As mentioned else where the CRN consists of National Highways (NH), State Highways (SH) and Major District Road (MDR). In order to prepare data collection plans, the existing GIS maps, RIS data, google earth imageries shall be used to the possible extent. The data available to date includes a list of all roads and links, the road -link length, Taluk and District maps. The plans shall be prepared in such a way that maximum road length can be surveyed with minimum dry run. During the initial stages a daily output of 60-70 lane km/day on the paved roads network shall be kept as target, and later it can be increased when the survey teams get fully acquainted with the prevailing conditions of the road network. The road data aimed to collect on various road categories is as follows

| Sr. No | Road Category | Types of Data |
|---|---|---|
| 1 | National Highways | Location Reference Points(LRP's), Road alignment |
| 2 | State Highways | Road Inventory and alignment, Road Condition, and LRP's |
| | | Pavement Strength |
| | | Pavement Layers details |
| 3 | Major District Roads | Road Inventory and alignment, Road Condition, and LRP's |
| | | Pavement Strength |
| | | Pavement Layers details |

# 2. Inventory and Condition - ROMDAS Survey

## 2.1 Installed / Configured ROMDAS Components

ROMDAS system is configured with various equipments for collecting inventory and condition data. The equipments/ accessories installed on the ROMDAS survey vehicle are as mentioned below

- ROMDAS Hardware Interface;
- Power Distribution box;
- Odometer sensor to measure the distance;
- Laser Profilometers to measure roughness;
- Laser Rut Measurement System (LRMS) to measure rut depth;
- GPS receiver for capturing spatial data;
- Video Cameras for Right of Way (RoW) and Pavement;
- 58 key configurable ROMDAS keyboard for inventory and visual condition
- Computer monitor;
- Other cable connections.

The guidelines related to the equipments installation are provided in the respective sections / chapters of *ROMDAS User's Guide* which was supplied along with ROMDAS systems. The schematic representation of ROMDAS equipment is as shown in Figure 2-1.

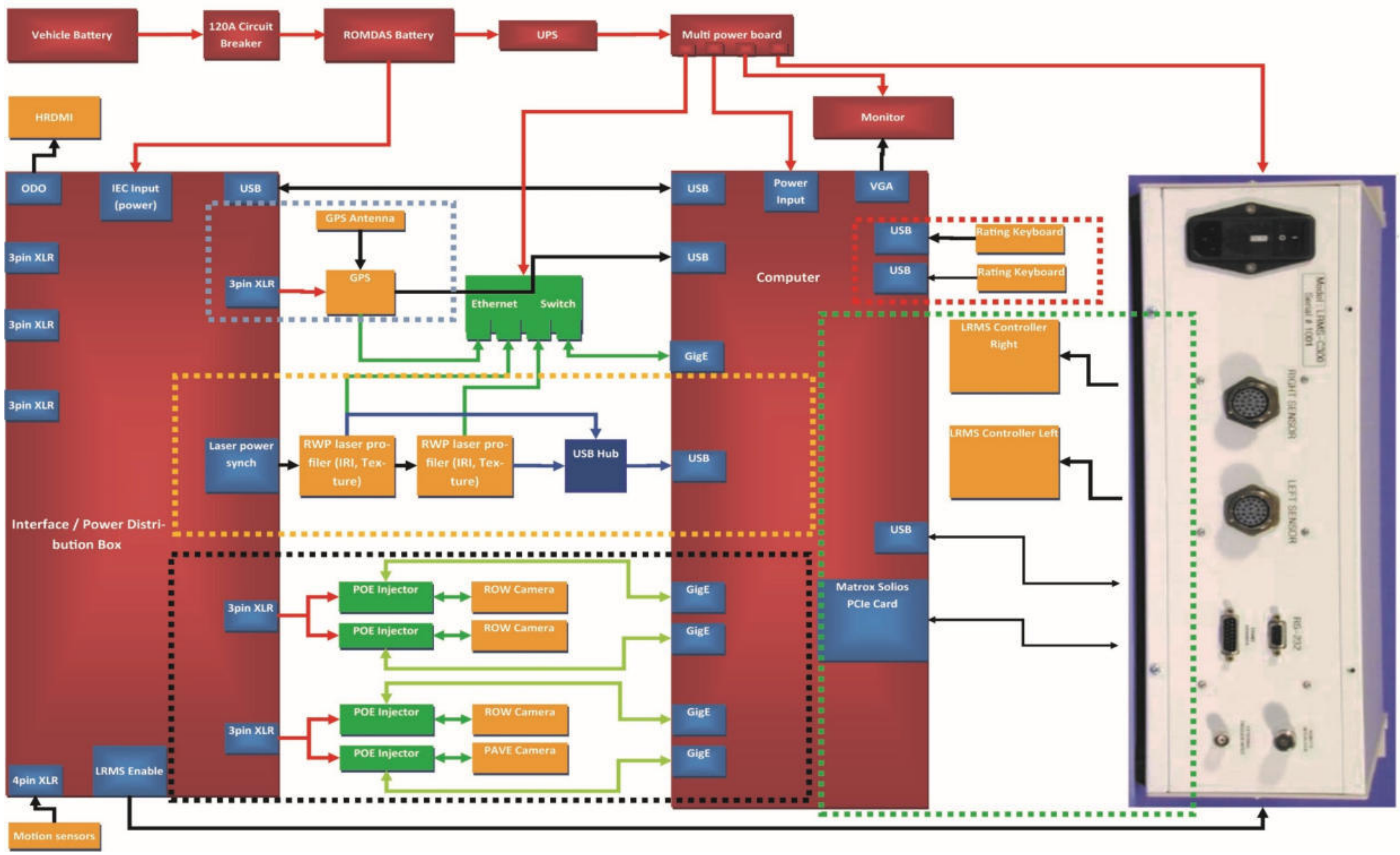



**Figure 2-1: Schematic Layout -ROMDAS**

## 2.2 Main Components of ROMDAS

### *2.2.1 Power Distribution Box (PDB)*

There are multiple ROMDAS instruments which need power supply for the functioning. For this purpose Power Distribution Box (PDB) plays an important role in supplying power to different hardware components of ROMDAS and to the computer. ROMDAS is configured with a PDB as shown in Figure 2-2.

**Figure 2-2: Power Distribution Box (PDB)**

### *2.2.2 Rack Mounted Hardware Interface*

The rack mount hardware interface is used for storing data and for operation of ROMDAS software and provide communication ports for the hardware components of the ROMDAS (Figure 2-3). This rack mounted hardware interface is mounted on the middle of the vehicle floor, such that it is in the easy access of surveyors for operation and cross checking.

**Figure 2-3: Rack Mounted Hardware Interface**

### 2.2.3 High Resolution Distance Measuring Instrument (HRDMI)

The High Resolution DMI sensor (HR DMI) is equipped with the ROMDAS vehicles for measuring high resolution distance which is required for LRMS, Laser Profilometers, and GPS.

**Figure 2-4: HR- DMI**

### 2.2.4 Laser Profilometers (Roughness and Texture Depth)

The Laser Profilometers uses laser and accelerometer combination to measure the longitudinal elevation of the profile and road texture characteristics. The output of these profilers gives raw longitudinal profile and International Roughness Index (IRI) in m/km. Under PRAMC project, two profilometers are installed on ROMDAS vehicle, one profiler for each wheel path, for measuring the roughness and texture of the pavement (Figure 2-5). The lasers used in the profilometer are of Class 3B and it is controlled by Laser Interface key. The profilometers are connected to the Rack Mounted Computer / hardware interface via an Ethernet connection and powered through the Laser DMI Interface which is controlled by the keyed switch.


**Figure 2-5: Laser Profilometers**

### 2.2.5 Laser Rut Measurement System (LRMS)

The ROMDAS Laser Rut Measurement System (LRMS) is a transverse road profiling system which is fixed at the rear of the vehicle as shown in Figure 2-6. LRMS consists of two lasers covering carriageway width of 4m.


**Figure 2-6: LRMS Arrangement**

The two LRMS lasers are responsible for the measurement of the left and right side transverse profiles. Each unit is composed of a high-power laser line projector and a special camera to measure deformations of the laser line profile. The lasers used in the LRMS are of Class 3B and it is controlled by key on Laser controller.

### *2.2.6 GPS Antenna and Receiver*

The GPS antenna (Figure 2-7) is mounted on vehicle roof which catches the signals from satellites and sends to the receiver to record the spatial coordinates. GPS receiver (Figure 2-8) is used to record the spatial coordinates of various road attributes. Trimble SPS 461 receiver is used in ROMDAS.

**Figure 2-7: GPS Antenna**

**Figure 2-8: Trimble GPS receiver**

The antenna distance, laterally from the side of the vehicle and height above the ground level are measured and stored in the GPS settings and Trimble settings. These distances will be used to correct the data recorded so that the recorded coordinates represent the actual (true) road centre line at ground level.

### *2.2.7 Video Cameras - RoW and Pavement*

4 Nos of Point Grey Research (PGR) Zebra cameras (3 cameras for capturing Right-of-Way (RoW) details and 1 camera for pavement view capturing) are installed on the survey vehicle.

The cameras are mounted on the survey vehicle roof and positioned in such a way that they capture a good general view of the road ahead, the roadside furniture in sufficient detail and the pavement surface view. These video footages can be used to identify inventory of various road parameters during post processing of data. RoW video features are captured with 2 MP (1600 x 1200) resolution at 25 frames per second and Pavement surface video is captured with 5 MP (2448 x 2048) at 18 frames per second (mono) resolution. Video cameras are enabled with image stabiliser to negate the effect of the vehicle vibrations.

**Figure 2-9: Right of Way (RoW) Cameras**


**Figure 2-10: Pavement Camera**

The PGR camera system connects to the survey computer through Ethernet cable via Ethernet Hub. The camera is powered through the power injector and the video data is compressed using Pegasus Pic Video M-jpeg Codec compression software.

### *2.2.8 Configurable Keyboards (Inventory and Visual Condition)*

ROMDAS is equipped with two configurable keyboards having 58 programmable keys. One keyboard is used to record the inventory data while the other keyboard to record visual condition data. These keyboards are connected directly to the survey computer through a USB port. In ROMDAS system all the road data are grouped into events, which are named as (1) Point event, (2) Continuous event and (3) switch event

- **Point Events-** which something exists at a single location – e.g. km Post, traffic sign
- **Continuous Events -** spread over a section and are characterised by a start and end chainage- e.g., pavement condition, medians
- **Switch Events**- Special type of continuous events which are called as series of continuous events. These events are dependent on the other events within the same group. Generally surveyor would require to press two keys when changing the continuous events- one key is to end the previous condition and the other key is to apply the new condition. Switch events remove the need to press two keys. When the second key is

pressed the first event is cancelled automatically. Some of the switch events are, width standard, pavement condition etc.

As per the PRAMC data collection requirements the keys of each of these keyboards are programmed /configured and labelled (Figure 2-11). These configurations can be changed at any point of time in the future, as per then requirement. More details about the types of data events and the detailed procedure of configuring the keyboard keys is given in *ROMDAS User's guide- Appendix G.*

**Figure 2-11: Configurable Keyboard**

**Visual Condition Data:** The surveyor assesses the condition of the pavement in the survey direction over a 500 m section length and determines the condition value for each of the relevant parameters. The software prompts the surveyor with a series of beeps prior to the end of the 500m interval that the assessed condition data to be keyed in. On dual carriageways both increasing and decreasing lanes will be surveyed, therefore the data recorded refers to the inventory and condition data in the survey (travel) direction. For single carriageways the data refers to entire roadway.

### *2.2.9 Computer Monitor, Keyboard*

A computer monitor is mounted at the middle of the vehicle. It is configured as a dedicated data collection computer. Power saving and screen saver options are turned off so that these do not hamper the progress of the data collection. Operations of various equipments and monitoring of the data collection will be performed through this monitor. This computer should be kept as "clean" as possible by avoiding installing more software which are not required for running ROMDAS operations. The power supply for the computer is drawn from the vehicle battery through ROMDAS power distribution box. Computer keyboard will be used for recording the text comments and LRPs during the data collection.

**Figure 2-12: Computer Monitor, Keyboard**

The Rack mounted computer is configured with the following specifications

- i7 Processor;
- 8GB RAM Memory;
- 320 GB Internal SSD Drive;
- 3X2TB removable HHD for data storage and transfer;
- Windows-7 (professional) operating system;
- MS Office;
- Drivers and software required for operating ROMDAS system.

### 2.2.10 ROMDAS Software

ROMDAS system is equipped with the ROMDAS data acquisition software. This software is configured to meet the data collection requirements of PRAMC. These settings should not be modified by the surveyors in the field unless such need arises. These configuration settings are saved in storage, and shall be replicated during reinstallation of software, if such situation arises.

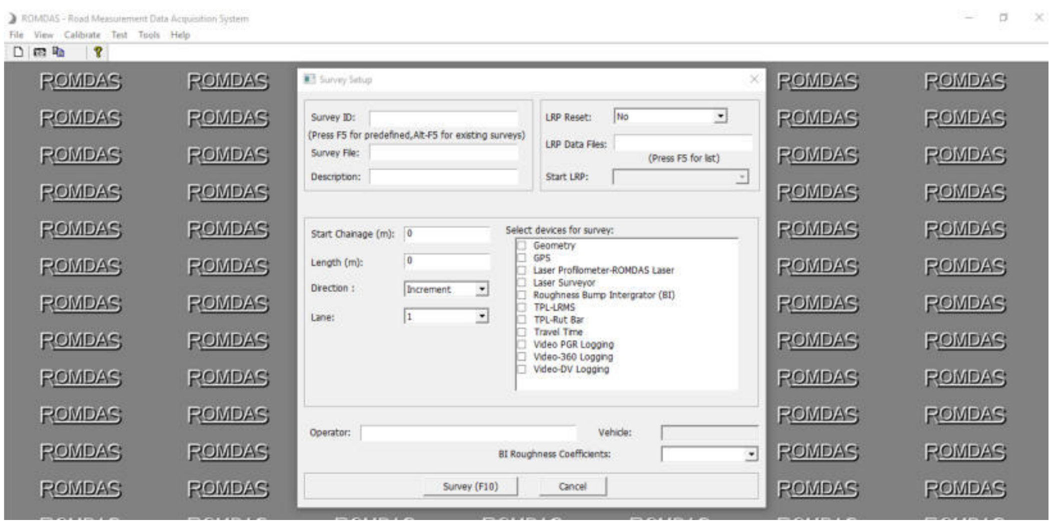



**Figure 2-13: ROMDAS Data Acquisition Software - Screen**

ROMDAS software is supplied with two modes of operations

**ROMDAS Registered Version –**is for data collection in the field; enabled for subsystems (equipments) purchased and installed in the computer of the survey vehicle;

**ROMDAS Office Version** – for office uses, this software is used for data processing, survey file setup etc.

## 2.3 Calibration and Validation of Equipment's

Prior to conducting any surveys it is necessary to calibrate the instruments / sub-systems. The following calibrations must be performed.

**Odometer Calibration:** This calibration ensures that the distance and speeds measured by the survey vehicle are correct. This calibration is to be performed at a frequency of **every 5000km** of survey. The procedure for the Odometer calibration is given in the *Calibrating the Instruments* section of the *ROMDAS User's Guide.*

**LRMS Calibration and Verification:** The LRMS installed on the survey vehicle are pre-calibrated before supply, which will not change under normal circumstances. However, this calibration can be verified or checked by using the *LRMS Calibration Object.* The procedure of verification or checking is provided in the *ROMDAS User's Guide* under Section 12.7: *LRMS Calibration Verification and Cleaning* section.

**Laser Profilometer**

- **Calibration:** The calibration of Laser Profilometer involves calibration of *Laser Odometer calibration* this defines the laser sampling distances, and the minimum speed laser safety cut-out. The detailed procedure of *Laser Odometer calibration* is given in the *ROMDAS User's guide.* The equipment used under PRAMC is pre-calibrated by the supplier. If this calibration test does not meet the requirements or the Profilometer or it is past its calibration expiry date, the Profilometer should be returned for calibration
- **Validation:** The accuracy of the Profilometer must be monitored with the Bounce checks. This measurement checks that all aspects of the Profilometer are working optimally and should be carried out daily before starting survey. The detailed procedure of Laser validation is given in the *ROMDAS User's guide.*

## 2.4 Pre-survey Activities

### *2.4.1 Training survey crew*

Prior to proceeding to the field surveys, the survey crew shall be given training in all activities related to equipment operations including inventory data entry, condition assessment and condition data entry. Upon completion of training a sample survey shall be performed by the team members under the supervision of the trainers. This exercise is very much required to assess the understanding levels of the survey team and to provide clarifications on the issues, which they may face during the survey.

### *2.4.2 Items carried for survey*

The below mentioned items are necessary for conducting the field surveys shall be carried to the field

**Table 2-1: Items carried for ROMDAS surveys**

| Sr. No | Description | Remarks |
|---|---|---|
| 1. | CRN Road Map | Printed copy |
| 2. | CRN road map electronic copy | On survey computer |
| 3. | ROMDAS Manuals | Printed copies |
| 4. | Survey vehicle with Survey Equipment | For Conducting survey |
| 5. | Back up External Drive (2TB) | Storing and Back up data |
| 6. | Measuring Tape | 30m length |
| 7. | Pressure gauge | To check tyre pressure |
| 8. | Traffic cones | To warn ongoing traffic during survey vehicle in stationary position |
| 9. | Mobile phone with charger | For communication |
| 10. | Tool Kit | To address small repairs |
| 11. | Internet Dongle(3G Capability) | For communication |
| 12. | Survey Log | For recording the issues in the field |
| 13. | Note Book / Note Pad | Recording the issues, status of work |
| 14. | Highlighters | For marking on the maps |

## 2.5 Starting ROMDAS survey

Survey vehicle should be positioned at least 100 m before the survey section start and open the ROMDAS software application which is installed on the computer of the survey vehicle. This extra warmup length would enable the vehicle to get minimum speed by the time it reaches the actual survey section start and also to condition the input filtering system. Upon opening ROMDAS software application a Start-up window will open with five different menu options as follows:

- File – Survey setup parameters and data processing;
- View – View processed data;
- Calibrate – calibrate the survey components;
- Test – test the instruments connected;
- Tools – Define Key code events and survey IDs, LRP utilities;

Detailed descriptions about the above mentioned functions are given in *ROMDAS User's guide.*

Test all equipment for proper operation as per the guidelines of *ROMDAS user's guide* and start the new survey by defining survey data as mentioned below:

Select **File/New Survey** and the survey setup screen appears (Figure 2-14). Enter the appropriate information in the relevant fields as mentioned below

- Survey ID – A unique code identifying the survey, in the PRAMC survey use the link name;
- Survey File – This defaults to the survey Id and should not be changed unless a repeat survey or part survey is required;
- Description– a brief description of the survey, for example from intersection with SH6 to road end at junction with SH2;
- Set *LRP Reset* to *Define*;
- Select devices for survey – these would be normally enabled automatically from the settings in **Default to use in Survey** fields for each instrument
- Enter the start chainage – this will be as per the details of the survey section;
- Enter equipment operator and vehicle details.

Once all the survey setup data is input, select “Survey (F10)” or press “F10” to get the survey screen and to commence the survey. At the completion of the survey, press the F10 key, which will open a window as shown in Figure 2-15.

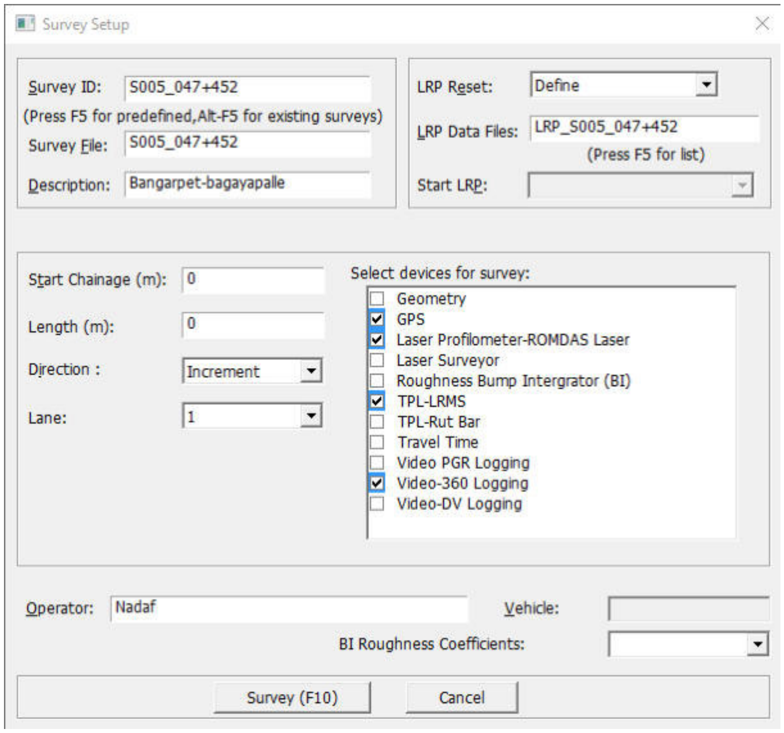



**Figure 2-14: Survey Start up /Setup Screen**

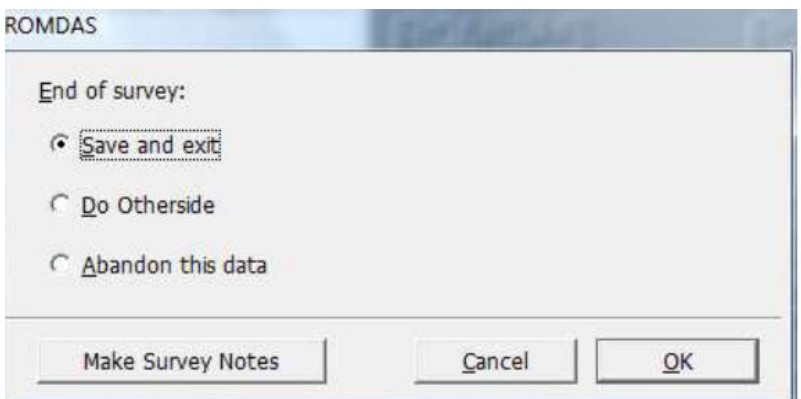



**Figure 2-15: End of Survey Screen**

Sometimes the operator has something to note about the survey such as the details of the end location of the survey etc. The ***Make Survey Notes*** button allows user to enter comments on the survey when the survey ends. This data is stored in the Memo field of the *Survey_Header* table in the output file. It is advised to end the day survey at such locations those can be easily identified while resuming the survey the next day. These locations could be junctions or villages or any other permanent structure.

## 2.6 Inventory and Visual Condition Data Collection

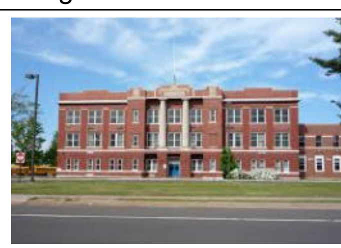
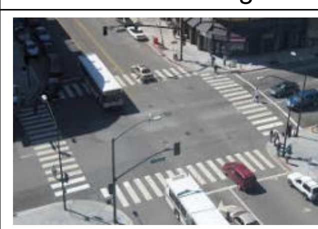
As part of Inventory and visual condition data collection the following data required to be collected.

- Location reference point (LRP) data;
- Road inventory data;
- Visual condition data;
- GPS data;
- ROW Video;

### *2.6.1 Location Referencing Point (LRP) Data*

The start and end of each road /link are fixed and defined by PWD, and all objects / assets on these are referred to the start /end of these road /link. However, in circumstances where the start and end points of the road /link are too far apart which may cause cumulative errors in the measurement. In order to reduce these cumulative errors, intermediate reference points called Location Referencing Points (LRPs) shall be identified and recorded during data collection. LRPs are to be located at a position which is deemed permanent in nature, and easily identifiable in the field, generally with maximum intervals of 5km. There would be more prominent structures in urban areas which can be used as LRP.  However in rural areas, it is proposed to identify LRPs between 1km (minimum) and 5km (maximum).The following are some of the objects which can be recorded as LRPs during field data collection.

**Table 2-2: Location Reference Points**

| | | |
|---|---|---|
|   |  |  |
| Kilometre Stone | Religious Structure | Permanent Buildings |
|  |  |  |
| Cross Drainage Structure | School / College | Intersection |

**Data Collection:** During the survey, the identified LRPs shall be recorded using the ROMDAS software by following the guidelines given in the *ROMDAS User's Guide, Section 8: Location Reference Point Surveys.*

### 2.6.2 Road Centre Line and GPS Data

As mentioned elsewhere in this document, ROMDAS is equipped with Differential Geographical Positioning System (DGPS), which records the GPS co-ordinates. These co-ordinates can be used to plot the road centrelines with reference to the spatial co-ordinates. The GPS coordinates are recorded automatically by ROMDAS at every 5m intervals and are automatically differentially corrected using the GPS Aided Geo Augmented Navigation (GAGAN) real time data correction stream, and recorded by the ROMDAS software as measured by Trimble SPS 461 receiver. The height of the antenna from the road surface and offset from the centreline shall be input in the ROMDAS software prior to the commencement of the surveys.

**Data Collection:** Start the ROMDAS software by double clicking on the start icon and follow the below mentioned steps.

- Select Test/Test GPS and confirm the GPS is operating correctly;
- Confirm the GPS is receiving data from sufficient satellites and so giving a valid PDOP reading;
- Start data collection;
- GPS data will be recorded at every 5m intervals.

### 2.6.3 Video Data- Right of Way (RoW) and Pavement

The video data containing all the assets which are in RoW are automatically be collected using video cameras of the ROMDAS which includes a 3-camera digital imaging system incorporating 1 front, 2 side asset views. The video of the pavement will be captured by 1 rear-camera facing pavement.

**Data Collection:** As the survey proceeds, ROMDAS video cameras records the videos and stamps *Header data* on the video footage. The *Header Data* includes filename (survey_id), chainage, vehicle speed and the GPS coordinates.

### 2.6.4 Road Inventory

As a part of road inventory data collection, the details of items such as surface type, width of carriageway, width standard, shoulder type, are collected using the programmable keyboards of ROMDAS. The layout of the labelling of the inventory keyboard is shown in Figure 2-16.


**Figure 2-16: Labelling of Inventory Keyboard**

The ROMDAS interface automatically assigns linear chainage and GPS co-ordinates to these inventory items. The inventory data items, method of data collection, and key code configurations are shown in Table 2-3. These configurations can be changed at any point of time in the future, as per then requirement.

**Table 2-3: Road Inventory – Key code Configuration**

| Key code Configuration | Data Item | Key code Labelling |
|---|---|---|
| a | Street Light | Street Light Start |
| d | | Street Light End |
| n | Pavement Edge Marking | Pavement Edge Marking Start |
| o | | Pavement Edge Marking End |
| PGUP | Overlap | Overlap Start |
| HOME | | Overlap End |
| x | Median | Median Start |
| y | | Median End |
| v | Foot Path | Foot Path Start |
| w | | Foot Path End |
| e | Crash Barrier | Crash Barrier Start |
| f | | Crash Barrier End |
| l | Centreline Marking | Centreline Marking Start |
| m | | Centreline Marking End |
| A | Bridge | Bridge Start |
| B | | Bridge End |
| p | Accident Zone | Accident Zone Start |
| q | | Accident Zone End |

| Key code Configuration | Data Item | Key code Labelling |
|---|---|---|
| I | Pavement Type | Bitiminous |
| J | | Concrete |
| K | | Unsealed |
| E | lane width | 3.75 |
| F | | 5.5 |
| G | | 7 |
| H | | 10 |
| P | Shoulder Width | 1 |
| Q | | 1.5 |
| R | | 2 |
| ? | Drain | Lined drain |
| ~ | | Unlined drain |
| \ | | No Drain |
| T | Shoulder Elevation | Shoulder Drop |
| S | | Levelled Shoulder |
| U | Shoulder type | Paved Shoulder |
| V | | Gravel Shoulder |
| Z | Agriculture Land | Agriculture Land |
| b | Bus Stop | Bus Stop |
| L | Cautionary Signs | Cautionary Signs |
| Y | Commercial Land | Commercial Land |
| 0 | Forest Land | Forest Land |
| h | Hectometer stone | Hectometer stone |
| i | Industrial Land | Industrial Land |
| 8 | information sign | information sign |
| j | Junction | Junction |
| k | Kilometre Stone | Kilometre Stone |
| O | Mandatory Signs | Mandatory Signs |
| C | Minor Bridge | Minor Bridge |
| W | Mixed Land | Mixed Land |
| M | Religious Structures | Religious Structures |
| z | Residential Land | Residential Land |
| g | Road Boundary Stones | Road Boundary Stones |
| D | Culvert | Culvert |
| NUM_- | Educational Institutes | Educational Institutes |
| s | Speed Breaker | Speed Breaker |
| t | Tree | Tree |
| NUM_8 | Water Bodies | Water Bodies |

**Inventory Data Collection:** The inventory items observed along the survey route are keyed in by pushing the appropriate key of the configured inventory keyboard. During survey whenever a key on the keyboard is pushed, the distance, GPS coordinates, and the value of the defined parameter are recorded automatically by ROMDAS system interface.

### 2.6.5 Visual Condition Data

Visual condition data is collected using the semi-automated method (programmable keyboards of ROMDAS and visual observations) at an interval of 500 m. The condition ratings /ranges of various pavement condition data items considered as per the "Guidelines for Maintenance Management of Primary, Secondary and Urban Roads, IRC, 2004" shown in Table 2-4.

**Table 2-4: Pavement Defects Ranges – IRC**

| Defects | Range of Distress | | | | |
|---|---|---|---|---|---|
| Cracking (%) | >30 | 21 to 30 | 11 to 20 | 5 to 10 | <5 |
| Ravelling (%) | >30 | 11 to 30 | 6 to 10 | 1 to 5 | 0 |
| Pothole (%) | >1 | 0.6 to 1.0 | 0.1 to 0.5 | 0.10 | 0 |
| Shoving (%) | >1 | 0.6 to 1.0 | 0.1 to 0.5 | 0.10 | 0 |
| Patch (%) | >30 | 16 to 30 | 6 to 15 | 2 to 5 | <2 |
| Settlement and depression (%) | >5 | 3 to 5 | Up to 2 | Up to 1 | 0 |
| Rutting (mm) | >50 | 21 to 50 | 11 to 20 | 5 to 10 | <5 |
| Rating | 1 | 2 | 3 | 4 | 5 |

The labelling of the visual condition collection keyboard is shown in Figure 2-17. Details of the pavement condition data items along with the ranges which shall be used during the data collection given in Table 2-5 . These configurations can be changed at any point of time in the future, as per then requirement.

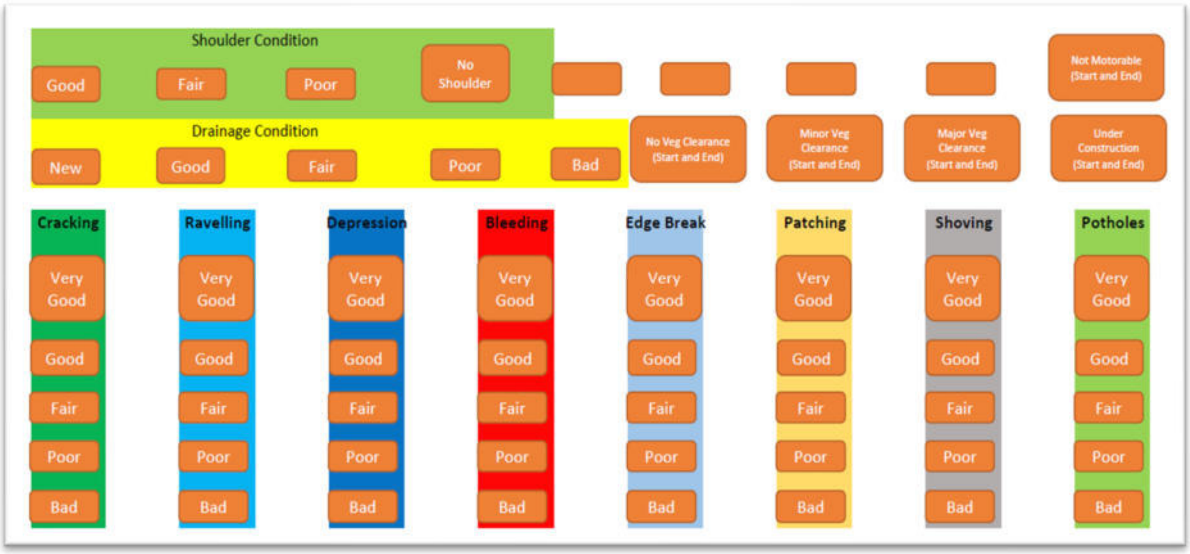



**Figure 2-17: Labelling of Visual Condition Keyboard**

**Data Collection:** The surveyor assesses the condition over a 500 m section length and determines the condition value for each of the relevant parameters. The computer provides alert the surveyor by an audible tone to that the assessed condition data to be keyed in. The surveyor presses the appropriate keys and the data to be applied to the respective 500 m section. The data which is keyed in will be locational referenced automatically by ROMDAS interface using the Distance Measuring Instrument (DMI) and Differential Geographic Positioning System (DGPS). Some of the typical examples for collecting the visual condition ratings are presented in Annexure-2.

**Table 2-5: Condition Key code Configuration- ROMDAS**

| Data Item | Key code Labelling | Classification | Key code Configuration |
|---|---|---|---|
| Cracking | Very Good | <5% | CTRL_a |
| | Fair | 5-10% | CTRL_c |
| | Good | 10-20% | CTRL_b |
| | Poor | 20 - 30% | CTRL_d |
| | Bad | >30% | CTRL_e |
| Ravelling | Very Good | 0% | CTRL_f |
| | Good | ≥1 to 5% | CTRL_g |
| | Fair | >5 to 10% | CTRL_h |
| | Poor | >10 to 30% | CTRL_i |
| | Bad | >30% | CTRL_j |
| Potholes | Very Good | 0 %; | } |
| | Good | 0-0.1 % | \| |
| | Fair | 0.1- 0.5%; | : |
| | Poor | 0.6- 1.0%; | " |
| | Bad | >1% | < |
| Shoving | Very Good | 0% | ( |

| Data Item | Key code Labelling | Classification | Key code Configuration |
|---|---|---|---|
| | Good | 0.10% | ) |
| | Fair | 0.1%-0.5% | _ |
| | Poor | 0.6%-1% | + |
| | Bad | >1% | { |
| Patching | Very Good | <2% | CTRL_z |
| | Good | 2 to 5 % | % |
| | Fair | 6 to 10% | ^ |
| | Poor | 11 to 30% | & |
| | Bad | >30% | * |
| Depression | Very Good | 0 | CTRL_k |
| | Good | up to 1 % | CTRL_l |
| | Fair | up to 2% | CTRL_m |
| | Poor | 3-5% | CTRL_n |
| | Bad | >5% | CTRL_o |
| Bleeding | Very Good | 0% | CTRL_p |
| | Good | 5% | CTRL_q |
| | Fair | 5%-10% | CTRL_r |
| | Poor | 10%-30% | CTRL_s |
| | Bad | >30% | CTRL_t |
| Edge break | Very Good | 0% | CTRL_u |
| | Good | <5% | CTRL_v |
| | Fair | 5-15% | CTRL_w |
| | Poor | 15-30% | CTRL_x |
| | Bad | >30% | CTRL_y |
| Drainage Condition | New | | PGDN |
| | Good | | ] |
| | Fair | | [ |
| | Poor | | , |
| | Bad | | ; |
| Shoulder Condition | Good | | ! |
| | Fair | | @ |
| | Poor | | # |
| | No Shoulder | | $ |
| Major Vegetation Clearance | Major Vegetation Clearance | | - |
| Minor Vegetation Clearance | Minor Vegetation Clearance | | = |
| No Vegetation Clearance | No Vegetation Clearance | | ' |
| Not Motorable | Not Motorable | | > |
| Under Construction | Under Construction | | / |

## 2.7 Pavement Roughness and Texture Data

As mentioned elsewhere, Roughness and Texture are measured using two laser profilometers, one each for the left and right wheel paths mounted on the rear side of the vehicle.

**Limitations:** The following limitations apply for ROMDAS Laser profilometers

- Standoff height (the height from the top of the laser to the ground) is 245mm, and the measuring range is ± 250mm from this standoff height.

- Minimum survey speed 20 kmph and maximum survey speed up to 100 kmph;
- Not recommended for operation in free standing surface water;
- Data quality is compromised by loose surface material;

**Warnings:** The Laser DMI key should be removed when the Laser Profilometer is not in use to ensure that it is not operated by untrained personal. The laser is equipped with a mechanical shutter to isolate the laser beam. Ensure the shutter is in the closed position when the Laser Profilometer is left unattended.

**Safety Precautions**: The exposure to laser radiation emitted from LRMS can be hazardous to the eyes, particularly if the exposure duration exceeds a few seconds while the viewer's eyes are at close proximity of the aperture from which the laser radiation is emitted (worst-case viewing scenario). LRMS system should not be used by anyone who is not aware of these dangers.

**Exceptional Situations:** The data collection should be paused in some of the exceptional cases

- Road works are underway
- On bridges
- Very low speeds

In such cases, during processing of the data roughness values of the excluded survey sections are estimated by the ROMDAS software, and detailed instructions are given in *ROMDAS User's guide.*

**Data Collection:** The settings and performance will be checked and tested under the *Test/Test Laser Profilometer* option within the ROMDAS software when required to test the ROMDAS laser IP connections.

- Connect all cables
- Connect the power to the Laser
- Start the laser Connections test
- Start the ROMDAS software data collection program and confirm system operation.

Roughness data to be collected in increasing direction for single lane road and on both increasing and decreasing lanes for two and above lane roads. On four lane roads (divided), the survey vehicle required to be driven on the outermost lane i.e., the lane nearest to the shoulder in each direction.

## 2.8 Pavement Rut Data

Laser Rut Measurement System (LRMS) is used to collect the pavement rut data.

**Data Collection:** Rutting data will be collected continuously at the sampling interval set in the LRMS settings. The data will be collected in the increasing direction on single lane road and on both increasing and decreasing lanes on two and above lane roads. On four lane roads (divided), the survey vehicle will be driven on the outermost lane, i.e., the lane nearest to the shoulder in each direction. The **'Test TPL-LRMS'** option is used to test the ROMDAS LRMS Laser.

- Connect all cables
- Turn on the LRMS key before to start the survey.
- Start the TPL_LRMS test and confirm system operation
- Start the ROMDAS software data collection program and continue survey.

**Safety Precautions**: The exposure to laser radiation emitted from LRMS can be hazardous to the eyes, particularly if the exposure duration exceeds a few seconds while the viewer's eyes are at close proximity of the aperture from which the laser radiation is emitted (worst-case viewing scenario). LRMS system should not be used by anyone who is not aware of these dangers. More information related to the laser distribution is given in *ROMDAS User Manual* under *Rut Depth Surveys LRMS Scanning Laser* section.

## 2.9 Daily Checks

Prior to starting the survey, the following checks shall be performed on daily basis

| **Sr. N°** | **Description** | ✔ | ✘ |
|---|---|---|---|
| 1 | Tyre pressure set to standard pressure (35 psi); | | |
| 2 | Engine oil | | |
| 3 | Fuel | | |
| 4 | System power; | | |
| 5 | Checking all nuts, bolts, connections, cables connected to computer and keyboards; | | |
| 6 | Cleaning of Lenses of LRMS, Video Cameras with a soft fabric using isopropyl-alcohol or methanol. | | |
| 7 | Checking ROMDAS Interface and odometer cables; | | |
| 8 | Testing the operations of , Hardware Interface, GPS, Video Cameras and Lasers | | |
| 9 | Hose conditions | | |

Upon completing all the above mentioned checks, survey can be started by switching on the vehicle, power and starting ROMDAS computer.

## 2.10 Survey Log

During field survey, survey log sheets (Annexure-1) will be maintained by the survey team to record the details of the survey and any other information or factors which may influence the data collection. The details contain the following information:

- Date of survey;
- Road ID
- Chainage ( From, To)
- Total Survey Length (km)
- Name of .rbf file
- Any issues occurred during data collection, and countermeasures taken
- Remarks to record any other information such as deviations from the main road, impassable road sections etc.

## 2.11 General

### *2.11.1 Survey Direction*

The survey direction is by default in the direction of increasing chainage as adopted by PWD and incorporated in the existing RIS database.

### *2.11.2 Multi lane Roads*

On multi-lane roads, ROMDAS survey will be conducted in both increasing and decreasing direction hence it will be necessary to distinguish the increasing and decreasing lane survey files. For this purpose increasing chainage and decreasing chainage lane files will be suffixed with “I” and “D” appropriately.

### *2.11.3 Naming of Survey Files*

All roads will be surveyed link by link with a new file for each link regardless of its length. The file name will be the same as the link number. For example the survey file name of link - BGR001 is BGR001_I for increasing chainage.

# 3. Falling Weight Deflectometer (FWD)

## 3.1 General

Pavement strength is assessed by measuring pavement deflection under a pre-determined load using a non-destructive equipment named Falling Weight Deflectometer (FWD). FWD is used to measure the vertical deflection response of a surface to an impulse load using the automated methods. The FWD which is used for data collection under PRAMC is in-vehicle mounted and this equipment comprises of an arrangement to simulate the dynamic load from truck on the pavement. The information collected using FWD can be used to determine (i) Bearing Capacity (ii) Layer Thicknesses (iii) Elasticity Moduli and (iv) Residual life (expected surface life). This FWD machine comprises of the following elements

**Table 3-1: Components- FWD Machine**

| Sr. N° | Component | Purpose |
|---|---|---|
| 1. | Load Plate - 4 split segmented | For transferring the load on to the pavement |
| 2. | Weight Pack | Various Configurations to apply the desirous loads |
| 3. | Geophone Sensors (9Nos) | For recording the pavement deflections |
| 4. | DMI | Distance Measuring Instrument |
| 5. | Global Positioning System | For recording the spatial coordinates |
| 6. | Temperature Sensors | To measure Ambient, Ground and In Ground temperature |
| 7. | Rugged Laptop | For operating FWD |
| 8. | Load Sensor / Cell (150kN) | To measure the load which is applied |
| 9. | FWD PaveTesting software | to collect the data and create the output files |
| 10. | Controller | to control the FWD Automatic Operations |

The FWD equipment is fixed on Tata Xenon 4x4 vehicle and it is in-vehicle mounted as shown in Figure 3-1.

Figure 3-1: FWD- in-vehicle mounted

## 3.2 Major components of FWD

### *3.2.1 Load Cell*

The load cell fitted to the FWD is designed to measure the load applied to the pavement during the deflection test. Designed with a central bore, the load cell is placed immediately above the loading plate for direct measurement of the loading force (stress). The load cell has a serial number, which is visible from the rear.

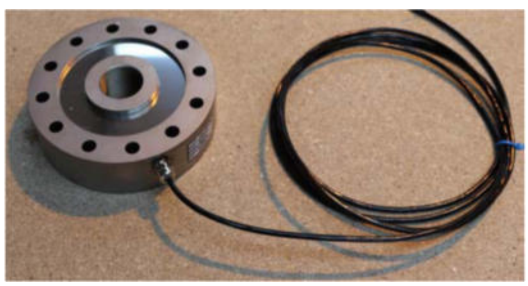


Figure 3-2: Load Cell

### *3.2.2 Load Plate*

Directly contacts the pavement surface to transmit the load. The load plate type used by PRAMC is solid, and it has a 300-mm diameter.

Figure 3-3: Load Plate

### 3.2.3 Geophone Sensors

The geophones of the FWD machine are used to measure the deflection on the pavement surface during the test with an accuracy up to microns. Under PRAMC, the FWD is equipped with 9 numbers of Geophones / Deflection sensors which are mounted at radial distances (in mm) 0, 200, 300, 450, 600, 900, 1200, 1500, and 1800 from the centre of the loading plate (Figure 3-5). Geophones are mounted in spring-loaded sensor support brackets suspended along the sensor bar. Each geophone has a unique serial number that is used to identify critical calibration information in the FWD data collection software. The geophones used in PRAMC FWD are of 2,000-micron.


**Figure 3-4: Geophone Sensor**

### 3.2.4 Sensor Bar

It is a long bar mounted above the load plate where the geophone holders are mounted. An extension of the sensor bar continues behind the load plate toward the hitch to allow a geophone to be mounted behind the load plate.

**Figure 3-5: Sensor Bar with Geophones**

### 3.2.5 Removable Weights

Removable weights mounted to the weight package. Their mass is 25 kilograms (kg) (44.1 pounds (lb)) each up to 300 Kgs is being used.

**Figure 3-6: Removable Weights**

### 3.2.6 FWD Controller

The FWD controller panel is mounted in the left hand side equipment bay and with its processors controls the FWD Automatic Operations. The controller sends the signals to the signal processor located in the vehicle through the multi-signal cable. Manual Operation can be performed with the use of the controller panel switches mounted on the lid of the controller panel, as per Figure 3-7. However in the current PRAMC FWD, this will be operated through Laptop.

**Figure 3-7: FWD Controller**

### *3.2.7 Temperature Sensor – In-ground temperature*

FWD is equipped with a temperature sensor for measuring the in-ground temperature (Figure 3-8). With the use of this sensor Sub-surface temperatures shall be measured by drilling 40mm depth holes in the bound layers of the pavement (holes that terminate in an unbound layer may be eliminated) in the centre of the outer wheel path (OWP).

**Figure 3-8: Sensor for In-ground Temperature**

### *3.2.8 Rugged Laptop*

The FWD is equipped with a rugged laptop. This (Figure 3-9) is used to perform automatic tests and to run the Pave Testing FWD software. The Computer is used to input site/test identification data as well as for displaying, storing, editing, sorting and further processing of FWD test data.

**Figure 3-9: Rugged Laptop**

### *3.2.9 Data Acquisition Software*

FWD is supplied with the PaveTesting FWD Software (Figure 3-10) which is installed on the supplied computer system. This is a standard executable file with additional installation files. This software is used to collect the data and create the output files which are compatible for the necessary further uses.

The output data files created by this software are

- Microsoft CSV for Peak Deflection Data
- Microsoft CSV for Time History Data

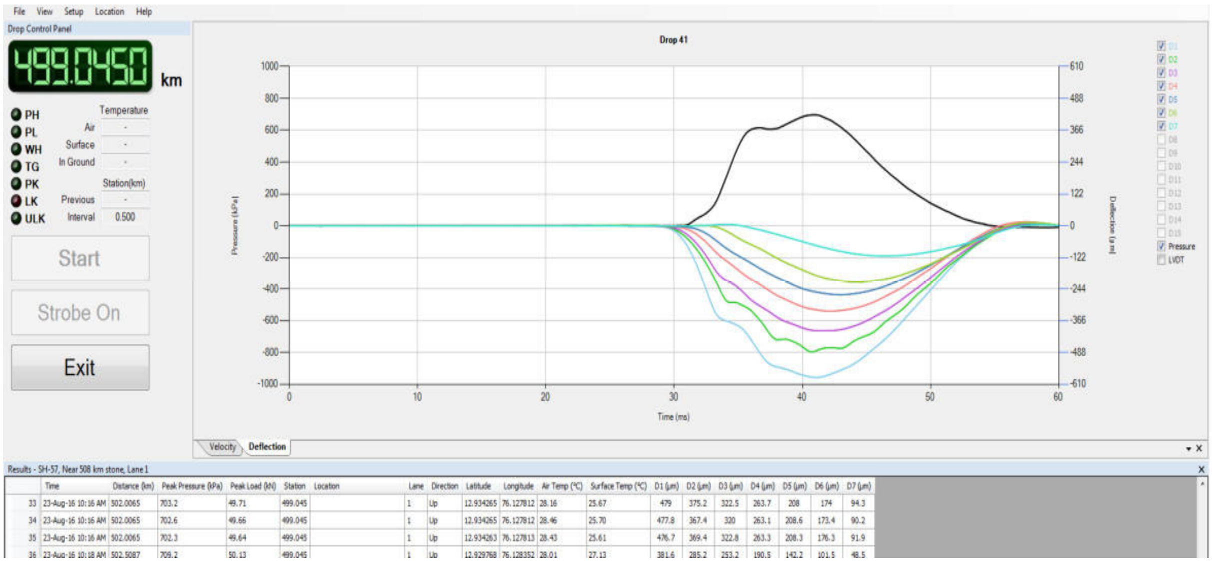



**Figure 3-10: Data Acquisition Software- FWD**

## 3.3 Calibration and Verification

### *3.3.1 Relative Calibration*

Relative calibration is a technique used to verify and adjust the response of each of the deflection sensors (geophones) so that equivalent measurements are obtained when the sensors are subjected to the same displacement. Relative calibration involves multiple drops and full rotation of all sensors in all positions in the stand. By rotating the sensors through all positions, any bias due to position in the stand is removed. If a sensor needs to be replaced, the relative calibration procedure can be used to compare it with the remaining sensors to determine a temporary gain factor for the new sensor. Frequent relative calibration of the deflection sensors will ensure that FWD is operating properly. The relative calibration should be performed using a relative calibration stand provided by the FWD manufacturer. It is recommended to contact the vendor whenever if it is deemed relative calibration is necessary i.e., if a major component such as a deflection sensor, multi-signal cable, or trailer PCB board is replaced.

If the FWD is in regular use, relative calibration should be performed on a nominal monthly interval. Relative calibration should not be performed during periods when the FWD is idle. If a major component such as a deflection sensor, multi-signal cable, or trailer PCB board is replaced, the FWD should undergo relative calibration regardless of the interval since the previous relative calibration. Deflection data should not be collected unless the FWD has undergone relative calibration within the previous 42 days.

### *3.3.2 DMI Calibration*

FWD equipment should undergo DMI calibration monthly while in service. Data should not be collected unless the FWD has undergone DMI calibration within the previous 42 days. If the vehicle undergoes maintenance, including replacement of tires, the DMI should be recalibrated before continuing to collect data, regardless of the interval since the previous DMI calibration.

The FWD-DMI is calibrated by driving the vehicle over a known distance. The FWD data collection software can then calculate an appropriate calibration factor. The section used for DMI calibration must be straight, and maximum of 15 m in length, and reasonably level. Because the FWD must be stopped at each end of the section, it cannot be performed on an active highway without traffic control. The section must be surveyed before the DMI calibration. The section should be measured using a surveyor’s tape (a measuring wheel is not acceptable). Ensure that the proper tension and alignment is applied to the tape. Immediately before DMI calibration, the tyre pressure for all of the vehicle tires should be set to the manufacturer’s specification (35 psi), and then the operator should drive the vehicle. After each DMI calibration the operator should fill out FWD DMI Calibration form presented in Annexure-3.

### *3.3.3 Temperature Sensor Verification*

Every temperature sensor collecting data associated with measurements should have its accuracy verified monthly, and unless the temperature sensor has been verified during the previous 42 days, data should not be collected. If a temperature sensor fails this procedure, it should be returned to the manufacturer for repair or recalibration, or it should be replaced with a new sensor.

**Temperature sensor verification procedure:**

a. Park the FWD and vehicle on a smooth surface in an area with good ventilation that is not exposed to direct sunlight.
b. Start the FWD data collection software and enter a screen from which the air and Infra-Red (IR) surface temperature measurements can be read.
c. Unclip the FWD air temperature sensor so that it hangs freely.
d. Prepare an ice water bath. Place ice and water in the 4 litre bucket and stir with the wooden spoon or paint stirrer. Stir until the reference temperature records a temperature that is less than or equal to 2 °C.
e. Place the bucket under the FWD air temperature sensor. When the reading from the IR temperature stabilizes, record the temperature from both the IR sensor and the reference

thermometer. Remove the reference thermometer, then stir the ice bath for 1 min, and record the measurements from both sensors again. If the recorded temperatures vary by more than 2 °C for either data set, stir for another minute, and then record both temperatures again. If the IR temperature sensor varies by more than 2 °C from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

f. Repeat the procedure in (e) for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

g. Stir the ice bath for another minute. Place the FWD air temperature sensor and the reference thermometer in the bath. When the reading from the air temperature sensor stabilizes, record the readings of both sensors. Stir for another minute and record both temperatures again. If the recorded temperatures vary by more than 2 °C for either data set, stir for another minute, and then record both temperatures again. If the air temperature sensor varies by more than 2 °C from the reference thermometer for two or more data sets, then the air temperature sensor is unacceptable.

h. Repeat the procedure in (e) for the hand-held temperature probe.

i. Prepare water bath of the room temperature. Empty the bucket and fill it with the water bath. Allow it to stabilise for 10 min and then stir for 1 min.

j. Place the bucket under the FWD air temperature mounted sensor. When the reading from the IR temperature sensor stabilises, record the temperature from both the IR sensor and the reference thermometer, Stir the water for 1 min and then record the measurements from both sensors again. If the recorded temperatures vary by more than 2 °C for either data set, stir for another minute and then record both temperatures again. If the IR temperature sensor varies by more than 2 °C from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

k. Repeat the procedure in (j) for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

l. Stir the water for another minute. Place the FWD air temperature mounted sensor and the reference thermometer in the water. When the reading from the air temperature sensor stabilizes, record the readings of both sensors. Stir for another minute and record both temperatures again. If the recorded temperatures vary by more than 2 °C (3.6 °F) for either data set, stir for another minute and then record both temperatures again. If the air temperature sensor varies by more than 2 °C (3.6 °F) from the reference thermometer for two or more data sets, then the air temperature sensor is unacceptable.

m. Repeat the procedure in (l) for the hand-held temperature probe.

n. If any IR temperature sensor was determined to be unacceptable in the low temperature or ambient temperature check, then it need not be checked at the high temperature. The high temperature check is optional if it is being performed in the field. The high temperature check is to be performed only for IR temperature sensors.

o. Prepare the high-temperature oil bath. Pour cooking oil into the cooking pot to a depth of approximately 50 mm. Place the cooking pot on the hot plate and under the FWD air temperature mounted sensor. Stir the oil while it is warming on the hot plate. The operator who is stirring the oil must wear gloves. Heat until the oil temperature stabilizes at 60 °C as determined using the FWD IR temperature sensor.

p. Record the FWD IR temperature sensor and reference thermometer readings. Wait 5 min, and then record both sensors again. If the recorded temperatures vary by more than 2 °C for either data set, then wait 5 min and record both temperatures again. If the IR temperature sensor varies by more than 2 °C from the reference thermometer for two or more data sets, then the IR temperature sensor is unacceptable.

q. Repeat the procedure in (p) for the hand-held IR temperature sensor. Hold the hand-held IR temperature sensor at a height consistent with the FWD-mounted IR temperature sensor.

## 3.4 Software Settings and Configuration

### 3.4.1 Settings

Prior to commencement of FWD surveys, settings related to Application, the Machine and the Drops need to be adjusted as per the requirement. The SETUP section of the FWD system (software) facilitate the operator to modify these settings, the parameters which can be setup under each of these settings are as follows.

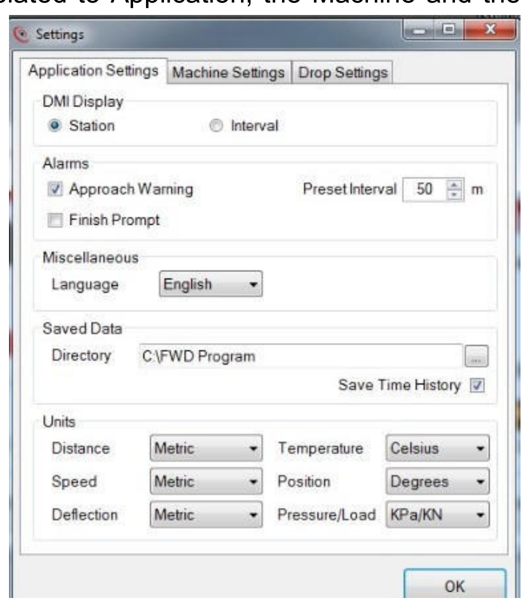



Figure 3-11: FWD Settings

**Application Settings:** This is used to setup the parameters including DMI Display, Language, Alarms, and the Directory to save the data, and Measurement units. All Measurement units should be in International System (SI) units.

**Machine Settings:** These settings are used to define the number of Geophone Sensors, sampling time, load plate size and catch pressure.

**Drop Settings:** A number of drop heights can be pre-programmed in this page allowing quick selection when performing tests. New Drop sequences can be created and deleted. Heights or Pressure can be selected. Max Height not to exceed 300mm.

The above mentioned settings are adjusted to the local conditions and have been input in the FWD software. These settings shall not be altered without any logical reason, as the change in the settings will affect the operation and performance of the FWD equipment. Further detailed instructions on how to enter these settings into the software are given in the *Pave Testing Data Collection Software Manual*.

#### *3.4.2 Configuration of Screen Layout*

The FWD test screen layout shall be configured by adding the system which is being used. The screen layout generally includes, Deflection and Velocity Charts, GPS data, and Tabulated results.

### 3.5 Load Levels

Five load levels are defined for uses under PRAMC. The acceptable load range for each drop height is between 90 percent and 110 percent of the target value. Setting the drop load at 103 percent of the target load at the beginning of the day will minimize the deviation over the course of the day for most cases.  Each drop height must be such a way that the targeted load is within the acceptable range. In order to achieve Target Load of 40kN (9kips) (acceptable range 36.0 to 44.0kN (8.1 to 9.9 kips)) the adjustments in the drop height should be performed whenever it is required.

### 3.6 Preparation for Field Survey

#### *3.6.1 Identification of Homogeneous Sections*

FWD data required to be collected on a sample length of 2,500km of Core Road Network (CRN). The representative road sections for conducting FWD survey shall be identified determined according to the IRC 115-2014, by considering the distress condition rutting and cracking the appropriate test plan will be prepared. The crack free test section with rut 0-20mm are considered for the test. This includes the good sections with rutting 0-10 mm and moderate sections with rutting 10-20 mm, while giving due consideration to the geographical conditions, districts boundaries, soil condition, traffic, connectivity and other factors. The test results of these homogeneous sections will be applied on the remaining sections with similar conditions.

### *3.6.2 Training survey crew*

Prior to proceeding to the field surveys, the survey crew need to be given training in all activities related to equipment operations and a sample survey need to be performed by the team members under the supervision of trainers. This exercise is very much required to assess the understanding levels of the survey team and to provide clarifications on the issues, which they may face during the survey.

### *3.6.3 Items carried for surveys*

The following items shall be carried to the field for collecting FWD

**Table 3-2: Items carried for FWD Survey**

| Sr. No | Description | Remarks |
|---|---|---|
| 1. | User Manual for GPR and FWD Hard/Soft Copies | For reference and guidance |
| 2. | FWD Complete Equipment Connected with Power Supply unit (Inverter and Battery) | For conducting survey |
| 3. | CRN-Map | Printed Copy |
| 4. | FWD Stretches- List | Printed Copy |
| 5. | Map of FWD Stretches | For reference |
| 6. | FWD Survey Schedule | Printed Copy |
| 7. | FWD Survey Procedure | Respective sections of the Data collection Procedure Report |
| 8. | Log book for recording equipment related issues | For recording the issues in the field |
| 9. | 15 Meter Measuring Tape | To measure distance |
| 10. | Road Marking Paint kit with Hand Driven Wheel. | For DMI calibration |
| 11. | Glycerine bottle | To measure in-ground temperature |
| 12. | Drilling Machine Set (Drilling Machine, Battery , Charger, Bits of various Sizes) | For making holes in Pavement to measure temperature |
| 13. | Thermometer | To check In ground Temperature |

| Sr. No | Description | Remarks |
|---|---|---|
| 14. | 1 Set Walky-Talky hand sets and chargers | For communication between crew members |
| 15. | Traffic Cones | For safety During test |
| 16. | Pens / Pencil | To prepare notes |
| 17. | Note Book / Note Pad | To prepare notes |
| 18. | Highlighters | For marking on the maps |
| 19. | Internet Dongle(With Minimum 3G Capability) | For the Remote Support |
| 20. | Mobile phone with charger | For communication |

## 3.7 Survey Procedure

### *3.7.1 Interval of Tests*

FWD survey will be carried out with the spacing of tests as mentioned below:

- For Double lane roads - 1 kilometre spacing (interval) in each lane/direction (staggered). This spacing is equivalent to 500m between tests and equates to 2 tests per (road) kilometre.
- For Single lane roads testing in one direction only - at 500m spacing. This gives the same numbers of test frequency as for double lanes above.
- For Intermediate roads, where a return journey along the same road is required (for example where this is the shortest connection to the next survey road), testing in both directions at 1 kilometre spacing - as for double lane road. Where it is excessively time consuming to return on the same road, testing to be carried out in one direction, however with staggered tests at 500m spacing on the opposite side of the road.

### *3.7.2 Deflections Measurement*

When an FWD operator arrives at the site, operator should inspect the test section for evidence of maintenance activities.

- Position the FWD so that the centre of the load plate is on the section start limit (i.e., Station 000.000). Set the DMI to 0 centimetres (cm), ascending
- Position the FWD at the first test location
- In the FWD data collection software, set the “Test Setup”/ Road name. Then open a new data file. Use the file name from pre-existing list

- Enter the lane specification appropriate to the test location in the field provided in the data collection software
- Exit the vehicle during testing and examine the pavement surface in the vicinity of the FWD for distresses and defects
- Start the testing sequence while the geophones are lowered to the pavement, the weight is raised and 5 drops conducted at each test point
- The target load of 40kN which corresponds to the load on one dual wheel set of an 80kN standard axle load will be applied and deflection at radial distances (in mm) 0, 200, 300, 450, 600, 900, 1200, 1500, and 1800 from the centre of the loading plate will be measured by using the geophone sensors
- After completing each test point in the pass, close the data file. The data file must be closed and a new data file opened before beginning in a new test pass
- Return the FWD to the section start limit (i.e., station 000+000), and return the DMI to zero
- After testing is complete and the load plate is up, proceed to the next test point

### *3.7.3 Temperatures Measurement*

FWD temperature sensors are used to collect the air, ambient temperature, sub-surface temperatures. Air, and Ambient temperatures are measured automatically by the respective temperature sensors. Sub-surface temperatures shall be measured by drilling 40mm depth holes in the bound layers of the pavement (holes that terminate in an unbound layer may be eliminated) in the centre of the outer wheel path (OWP). The tolerance for holes is ±10 mm. Allow extra time for the heat generated during drilling to dissipate. If a hole is within ±25 mm of the reported bottom of the bound layers, its depth should be decreased to 25 mm above the reported bottom of the bound layers. Holes should be drilled with a portable hammer drill using a 13-mm (0.51-inch) diameter bit. After the hole is drilled to the required depth, it should be cleared of debris and dust by blowing through a short piece of plastic tubing or other suitable device. The actual depth of the hole should be measured after it is cleared of debris. Then it should be filled with 15 to 25 mm of mineral oil (glycerine) to provide thermal conductivity between the pavement and the temperature probe. The hole should be covered with tape (such as duct tape) and the tape slit to allow the FWD probe to be inserted.

### *3.7.4 File Naming*

The file name for an FWD data file should be eight characters in the following format: Road Category-Road Number-Km Start Chainage – Km End Chainage. Where

Road Category: SH, MDR; Road Number: 1, 2, 3, 4, 5. etc; Km Start Chainage: 000.000, Km End Chainage: 100.000.For example: Road SH 99 surveyed from Ch: 000.000 to Ch: 100.000 the file Naming will be SH-99-000.000-100.000.

The details of the FWD survey along with the core details are entered in the Form which is shown in Annexure-3.

## 3.8 Regular Checks

### *3.8.1 Checks of Vehicle*

The operator should perform the following checks on the vehicle before the start of travel for the day:

**Regular Vehicle Checks- FWD**

| Sr. Nº | Description | ✔ | ✖ |
|---|---|---|---|
| 1 | Fluid levels | | |
| 2 | Engine oil | | |
| 3 | Brake fluid | | |
| 4 | Power steering | | |
| 5 | Wiper fluid | | |
| 6 | Coolant | | |
| 7 | Transmission fluid | | |
| 8 | Battery connections | | |
| 9 | Hose conditions | | |
| 10 | Tires inflated properly and in good condition | | |
| 11 | Lights operational | | |
| 12 | Headlights | | |
| 13 | Taillights | | |
| 14 | Turn signals | | |
| 15 | Brake lights | | |
| 16 | Strobe lights | | |
| 17 | Interior uncluttered, equipment stowed well | | |

### *3.8.2 FWD Checks*

The operator should perform the following checks on the FWD before the start of travel for the day:

**Start of Travel Checks- FWD**

| Sr. Nº | Description | ✔ | ✘ |
|---|---|---|---|
| 1 | Battery connections good. | | |
| 2 | Transport locks engaged. | | |
| 3 | Hitch pin in front sensor bar guide. | | |
| 4 | Covers and latches secure | | |

### 3.8.3 Pre-operational Checks FWD

At a minimum, the FWD operator should perform the following checks after the FWD arrives at the test site and before testing begins:

**Pre Operational Checks- FWD**

| Sr. Nº | Description | ✔ | ✘ |
|---|---|---|---|
| 1 | Transport locks unlocked. | | |
| 2 | Hitch pin / Cover removed from front sensor bar guide. | | |
| 3 | Hydraulic oil level good. | | |
| 4 | Raise/lower bar cable not frayed and well adjusted. | | |
| 5 | Geophones well-seated in geophone holders. | | |
| 6 | Geophone holder springs and foam guides in good condition. | | |
| 7 | Ribbed rubber sheet on load plate in good condition. | | |
| 8 | Load plate swivel free-moving. | | |
| 9 | Pressure switch boots in good condition. | | |
| 10 | Control box electrical connections tight. | | |
| 11 | Buffers have no cracks or slits, and are level and tight. | | |
| 12 | In addition, the operator should observe and listen to the hydraulics during the buffer warm-up sequence to ensure that they are free of air and operating correctly | | |

### 3.8.4 Post Operational Checks- FWD

At a minimum, the FWD operator should perform the following checks before leaving the test site:

## Post Operational Checks- FWD

| Sr. Nº | Description | ✔ | ✘ |
|---|---|---|---|
| 1 | Transport locks engaged. | | |
| 2 | Hitch pin/Cover replaced in front sensor bar guide. | | |
| 3 | Access doors locked. | | |
| 4 | All supplemental testing equipment properly stowed. | | |
| 5 | Table's filed out, dated, signed, and filed | | |
| 6 | Do check all cables are intact/ not damage before starting. | | |
| 7 | Do check all geophones Holder / Geophones Pins are tight and in place | | |
| 8 | Do check all Sensors/ Nuts & bolts are tight | | |
| 9 | Do check if there is any hydraulic oil leakage/ damage hose pipe | | |
| 10 | Do clean all assemblies daily | | |
| 11 | Do not keep bags etc. around FWD assembly | | |
| 12 | Check Hydraulic oil level/if needed top up weekly | | |
| 13 | In case there is connectivity problem | | |
| | • Check & ensure IP address setting | | |
| | • LAN cable/ connection | | |
| | • Check & re do all Geophones connection | | |
| 14 | Do not change in any settings in software | | |
| 15 | On the Geophone beams spare connectors/ socket should be close using cap to avoid any ingress of water or dirt. | | |
| 16 | At Bridges FWD test should be conducted approx. 50 Meters away from the Approaches of the Bridges and at culverts FWD Testing should be avoided. | | |

FWD should be maintained in accordance with the manufacturer's recommendations all maintenance and repair activities performed on PRAMC-operated FWDs should be documented using the form shown in Annexure-3.

## 3.9 Data Checks during Survey

For ensuring good quality data, several checks as mentioned below shall be performed during the survey;

### *3.9.1 Roll-Off*

"Roll-off" is an error condition that results when the deflection of the pavement surface as recorded by a deflection sensor does not return to near zero within 60 ms of the trigger activation. Unless the pavement structure is weak enough to be permanently deformed by the load pulse, this is not a believable measurement.

Roll-off can be caused by poor contact between the deflection sensor and the pavement surface. This error can be incorrectly triggered when magnitude of the deflection approaches the resolution of the geophone. Thus, roll-off when the peak deflection is less than 25 μm is not necessarily indicative of error.

If the roll-off error is triggered on a deflection that is greater than 25 μm, then the operator should follow the error resolution instructions in *section 3.9.6*. Otherwise the measurement should be accepted and testing should continue.

### *3.9.2 Non-Decreasing Deflections*

"Non-decreasing deflections" is an error condition that results when the deflections measured by the deflection sensors do not decrease with increasing distance from the load plate. Deflections should always decrease with increasing distance from the load plate.

This condition can sometimes occur legitimately if there is a transverse crack or other discontinuity between the two sensors that exhibit the non-decreasing deflections. If the operator observes such a crack or discontinuity between the two flagged sensors, then the test should be accepted and the observation should be recorded at the "Comments" prompt.

Non-decreasing deflections can sometimes be triggered incorrectly when the magnitude of the deflections approaches the resolution of the deflection sensor. If the larger of the two deflections is less than 10 μm, then the test should be accepted, and testing should continue.

Non-decreasing deflection may sometimes occur between deflection sensors 1 and 2 on extremely weak pavements because of permanent deformation of the pavement by the FWD.

If the deflections are not small and there are no cracks or discontinuities, or the non-decreasing deflections are not between sensors 1 and 2 and the pavement is not very weak or very stiff, then this error usually indicates poor seating between one or both of the flagged sensors and the pavement surface. The operator should follow the error resolution instructions given in *section 3.9.7*.

### *3.9.3 Overflow*

"Overflow" is an error condition that results when a measured deflection exceeds the range of the deflection sensor. For the FWDs operated by PRAMC, this range is 2,000 microns (80 mils, or 0.08 inch). Deflections of that magnitude are only expected on extremely weak pavements or when testing using extremely high load levels. For testing at a PRAMC test section using the load levels specified in this document, it is not reasonable to expect that the deflections will exceed 2,000 microns. If this error is encountered during testing, it is likely that the flagged sensor does not have good contact with the pavement surface. The operator should follow the error resolution instructions given in *section 3.9.6*.

### *3.9.4 Load Variation*

"Load variation" is an error condition that results when the peak load for repeat drops at the same drop height varies by more than the amount specified in *section 3.5*. This condition can occur legitimately on weak pavements where the structure is damaged by FWD testing, or on pavements with a saturated base or subgrade layer (such as during the spring thaw in wet-freeze zones). It may also occur if the load plate is not seated properly on the pavement surface, either because of loose debris or irregularities in the pavement surface.

If this error occurs during testing, the operator should follow the error resolution instructions given in *section 3.9.7*.

### *3.9.5 Deflection Variation*

"Deflection variation" is an error condition that results when the load-normalized peak deflections for repeat drops vary by more than the amount specified in *section 3.5*. This condition can occur legitimately only if the stiffness of the pavement is changed by the FWD testing itself. This generally occurs only if the pavement is extremely weak or the unbound layers are saturated.

Deflection variations can occur as a result of uneven pavement surface conditions causing poor seating of the load plate or deflection sensors or vibrations generated by heavy equipment operating nearby, especially trucks traveling in adjacent lanes.

If this error occurs during testing, the operator should follow the error resolution instructions in *section 3.9.6*.

### *3.9.6 Dealing with Deflection Errors*

If deflection errors occur, the operator must attempt to identify the source of those errors. If the errors caused by the FWD equipment, then those problems must be fixed before testing continues. If the errors result from localized pavement conditions, the operator should reposition the FWD and comment on the condition. If the errors are the result of pavement conditions that are representative of the test section as a whole, or due to factors beyond the operator's control such as truck traffic, the operator should accept the error and comment on the condition.

Sections 3.9.1, 3.9.2, 3.9.3, and 3.9.5 detail possible causes of the various types of deflection errors. If the deflection errors appear to be to the result of truck traffic in an adjacent lane, the operator should attempt to pause the test sequence to allow the trucks to pass, and then continue the sequence during lulls in the traffic. If there are too many trucks for this method to be practical, the operator should provide a comment for drop sets that were potentially affected by the truck traffic.

Operators must be very careful to not to overlook the FWD equipment itself as the source of the error. The following list is a summary of the troubleshooting process that is recommended in all cases, and the operator should deviate from the process only when confident of the source of the error, and the error source is not well suited for resolution using this troubleshooting process.

a) For the first such error at a test location, it is recommended that the operator get out of the vehicle and check the flagged deflection sensor (or sensors). Check that the deflection sensor is seated securely in the sensor holder, that the screws retaining the sensor magnet and sensor holder are tight, that the deflection holder is not resting on a loose stone or crack, and that the holder springs and foam bushing are in good shape.
b) If several sensors are flagged, it is recommended that the operator check all analog connections: sensor to control box, control box to multi-signal cable and multi-signal cable to signal processor.
c) The data should be rejected and the test repeated without repositioning the FWD.
d) If the errors persist, the operator must reject the test and perform the optional activities in mentioned in sections (a) and (b). If problems with the equipment are discovered and corrected, all data collected in this test pass should be discarded, and the test pass should be restarted.
e) If errors persist and the test being performed is a load transfer test, or if the FWD cannot be moved forward because of a joint or transverse crack, then the results should be accepted whether or not they contain errors. The operator should enter a comment stating "Error could not be resolved."
f) If the errors persist and the FWD can be repositioned, the operator should reject the data and move the FWD forward by 0.6 meters. The operator should repeat the test a fourth time. If the errors persist the operator should accept the results and at the prompt enter a comment stating "Error could not be resolved."
g) If the error could not be cleared, then for all subsequent errors of the same type in the same test pass the activities listed in sections (a) and (b) need not be repeated.

### *3.9.7 Dealing with Load Errors*

If load errors occur, the operator must attempt to identify the source of those errors. If the errors result from problems with the FWD equipment, then those problems must be fixed before testing continues. If the errors are caused by localized pavement conditions, the operator should reposition the FWD and comment on the condition. If the errors are caused by pavement conditions that are representative of the test section as a whole, the operator should accept the error and comment on the condition. *Section 3.9.4* gives details of the possible causes of load errors.

Operators must be very careful to not to overlook the FWD equipment itself as the source of the error. The following summary of the troubleshooting process is recommended in all cases, and the operator should deviate from it only if confident of the source of the error and the error source is not well suited for resolution using the troubleshooting process.

a) The data should be rejected and the test repeated without repositioning the FWD.
b) If the error persists, the operator should get out of the vehicle and check the equipment. All analog connections should be checked: load cell to load cell cable, load cell cable to control box, control box to multi-signal cable and multi-signal cable to signal processor. The weight height targets should be checked to ensure that they are tight. The load plate should be raised and the swivel checked to ensure that it moves easily. Check the rubber sheet and pavement surface under the load plate for debris, and remove any.
c) Reject the data and repeat the test without repositioning the FWD.
d) If errors persist and the test being performed is a load transfer test, or if the FWD cannot be moved forward because of a joint or transverse crack, then accept the results whether or not they contain errors. Enter a comment stating “Error could not be resolved.”
e) If the errors persist and the FWD can be repositioned, reject the data and move forward the FWD by 0.6m. Repeat the test a third time. If the errors persist then accept the results, and enter a comment stating “Error could not be resolved.”
f) If the error could not be cleared, then for all subsequent errors of the same type in the same test pass, the operator need not repeat the activities in step (b).

## 3.10 Corrections of Collected Data

- The data collected, deflections should be in decreasing order form geophone D1 TO D9.
- If any of the deflection from the sensor D1 to D9 is missing / more than it’s precede geophone, such values should be corrected with the average reading of the test data from the remaining Drop tests conducted at the same location.

- The first row of Deflections should not be blank. In case of any missing in data the complete drop test is omitted or the immediate drop in the same location is to be used for the back calculation.
- If the First Geophone Data/ majority of the Geophones data collected is invalid/Missing for all the drops at a Location. Such data should not be processed further.

### 3.11 Test Results – FWD

The data acquired by the FWD software can be exported to *.csv* format. A sample FWD test report containing the information of, geophone spacing, location referencing details, Drop ID, height of drop, applied pressure, deflections recorded by various geophone sensors, is shown in Table 3-3.

## Table 3-3: Results Table- FWD

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Available Sensors | 9 | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | D01 | D02 | D03 | D04 | D05 | D06 | D07 | D08 | D09 | | | | | | | | | | | | | | |
| 3 | Sensor Offset X | 0 | 200 | 300 | 450 | 600 | 900 | 1200 | 1500 | 1800 | | | | | | | | | | | | | | |
| 4 | Sensor Offset Y | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | | | | |
| 5 | Load plate size | 300 | mm | | | | | | | | | | | | | | | | | | | | | |
| 6 | Time | Location | Up/Down | Lane | Station (km) | Latitude | Longitude | DropID | Requested Height (mm) | Pressure (kPa) | Load (kN) | Air Temperature (°C) | Surface Temperature (°C) | In Ground (°C) | D1 (µm) | D2 (µm) | D3 (µm) | D4 (µm) | D5 (µm) | D6 (µm) | D7 (µm) | D8 (µm) | D9 (µm) | Remark |
| 7 | 19-04-2016 15:42 | palanahalli | Up | 1 | 155.75 | 13.44244 | 77.23636 | 1 | 129.8 | 601.11 | 42.49 | 40.37 | 29.14 | 42.3 | 706.85 | 484.37 | 311.12 | 224.6 | 132.2 | 102.59 | 72.42 | 65.39 | 34.58 | |
| 8 | 19-04-2016 15:42 | palanahalli | Up | 1 | 155.75 | 13.44244 | 77.23636 | 2 | 130.49 | 606.27 | 42.85 | 40.76 | 34.85 | 42.18 | 702.14 | 462.36 | 307.91 | 224.08 | 137.16 | 99.66 | 74.33 | 65.44 | 40.43 | |
| 9 | 19-04-2016 15:42 | palanahalli | Up | 1 | 155.75 | 13.44244 | 77.23636 | 3 | 130.26 | 611.07 | 43.19 | 40.52 | 32.81 | 42.09 | 696.27 | 460.41 | 307.58 | 223.71 | 139.2 | 102.72 | 73.52 | 67.92 | 27.16 | |
| 10 | 19-04-2016 15:42 | palanahalli | Up | 1 | 155.75 | 13.44244 | 77.23636 | 4 | 130.72 | 610 | 43.12 | 40.52 | 35.26 | 42.72 | 692.83 | 464.85 | 303.86 | 223.18 | 138.13 | 101.48 | 76.65 | 63.94 | 26.44 | |
| 11 | 19-04-2016 15:42 | palanahalli | Up | 1 | 155.75 | 13.44244 | 77.23636 | 5 | 130.03 | 609.81 | 43.1 | 40.49 | 28.9 | 42.21 | 689.06 | 471.23 | 301.85 | 223.46 | 140.16 | 103.1 | 74.81 | 66.47 | 24.66 | |
| 12 | 19-04-2016 15:45 | | Up | 1 | 156.25 | 13.44689 | 77.23648 | 6 | 130.15 | 605.61 | 42.81 | 40.43 | 27.55 | 42.48 | 893.05 | 641.91 | 420.74 | 310.38 | 199.74 | 146.04 | 109.17 | 84.84 | 50.04 | |
| 13 | 19-04-2016 15:45 | | Up | 1 | 156.25 | 13.4469 | 77.23647 | 7 | 130.26 | 611.16 | 43.2 | 40.7 | 29.08 | 42.51 | 889.98 | 640.02 | 422.8 | 314.46 | 201.8 | 148.92 | 109.98 | 88.24 | 50.04 | |
| 14 | 19-04-2016 15:45 | | Up | 1 | 156.25 | 13.4469 | 77.23647 | 8 | 130.15 | 609.75 | 43.1 | 40.82 | 32.48 | 42.42 | 884.66 | 636.91 | 420.1 | 313.91 | 202.99 | 151.19 | 109.72 | 88.73 | 50.04 | |
| 15 | 19-04-2016 15:45 | | Up | 1 | 156.25 | 13.4469 | 77.23647 | 9 | 130.15 | 610.41 | 43.15 | 40.94 | 22.76 | 42.45 | 880.8 | 640.22 | 417.71 | 312.71 | 203.2 | 148.54 | 111.94 | 86.44 | 50.04 | |
| 16 | 19-04-2016 15:45 | | Up | 1 | 156.25 | 13.4469 | 77.23646 | 10 | 130.72 | 612.33 | 43.28 | 41.12 | 30.03 | 42.48 | 879.97 | 639.34 | 422.33 | 313.43 | 203.1 | 147.47 | 112.51 | 89.9 | 50.04 | |
| 17 | 19-04-2016 15:47 | | Up | 1 | 156.75 | 13.45148 | 77.23658 | 11 | 129.69 | 616.65 | 43.59 | 40.52 | 20.71 | 42.42 | 555.83 | 395.75 | 299.03 | 237.27 | 168.7 | 112.92 | 80.46 | 58.92 | Invalid | |
| 18 | 19-04-2016 15:48 | | Up | 1 | 156.75 | 13.45148 | 77.23658 | 12 | 130.6 | 619.05 | 43.76 | 40.88 | 25.75 | 42.45 | 555.32 | 393.48 | 295.7 | 238.03 | 166.29 | 111.26 | 80.6 | 60.32 | Invalid | |
| 19 | 19-04-2016 15:48 | | Up | 1 | 156.75 | 13.45148 | 77.23658 | 13 | 130.15 | 619.77 | 43.81 | 40.91 | 21.85 | 42.57 | 552.07 | 404.36 | 295.2 | 238.39 | 167.98 | 112.78 | 80.24 | 61.33 | 4.56 | |
| 20 | 19-04-2016 15:48 | | Up | 1 | 156.75 | 13.45147 | 77.23658 | 14 | 130.26 | 619.77 | 43.81 | 41.24 | 24.26 | 42.57 | 554.71 | 399.69 | 294.12 | 237.35 | 164.73 | 111.6 | 83.38 | 59.81 | 10.18 | |
| 21 | 19-04-2016 15:48 | | Up | 1 | 156.75 | 13.45146 | 77.23658 | 15 | 130.72 | 623.13 | 44.05 | 41.73 | 29.76 | 42.66 | 557.96 | 402.59 | 295.69 | 239.63 | 165.43 | 113.01 | 84.34 | 61.11 | 0.04 | |
| 22 | 19-04-2016 15:50 | | Up | 1 | 157.24 | 13.45583 | 77.23548 | 16 | 130.49 | 614.84 | 43.46 | 40.88 | 26.95 | 42.63 | 841.34 | 590.23 | 391.97 | 289.26 | 171.89 | 112 | 77.28 | 61.71 | 47.42 | |
| 23 | 19-04-2016 15:50 | | Up | 1 | 157.24 | 13.45585 | 77.2355 | 17 | 129.92 | 611.55 | 43.23 | 41.03 | 36.32 | 42.51 | 814.16 | 569.76 | 388.76 | 281.29 | 171.96 | 103.67 | 79.7 | 65.88 | 45.35 | |
| 24 | 19-04-2016 15:50 | | Up | 1 | 157.24 | 13.45585 | 77.23549 | 18 | 130.26 | 612.36 | 43.29 | 41.36 | 25.65 | 42.57 | 813.38 | 567.57 | 384.84 | 282.56 | 173.53 | 102.57 | 79.9 | 64.84 | 46.04 | |
| 25 | 19-04-2016 15:50 | | Up | 1 | 157.24 | 13.45585 | 77.23549 | 19 | 129.8 | 615.06 | 43.48 | 41.39 | 24.99 | 42.63 | 817.12 | 576.32 | 384.9 | 280.27 | 171.89 | 109.66 | 80.32 | 66.05 | 44.03 | |
| 26 | 19-04-2016 15:51 | | Up | 1 | 157.24 | 13.45584 | 77.23549 | 20 | 129.58 | 611.54 | 43.23 | 41.51 | 26.59 | 42.69 | 816.8 | 579.84 | 382.64 | 286.69 | 172.59 | 106.39 | 80.36 | 66.32 | 43.39 | |
| 27 | 19-04-2016 15:53 | | Up | 1 | 157.73 | 13.46007 | 77.2341 | 21 | 130.6 | 605.88 | 42.83 | 41.21 | 27.98 | 42.81 | 660.37 | 442.78 | 291.97 | 204.86 | 113.82 | 74.82 | 60.53 | 52.71 | 40 | |
| 28 | 19-04-2016 15:53 | | Up | 1 | 157.73 | 13.46007 | 77.23409 | 22 | 130.49 | 606.24 | 42.85 | 41.48 | 28.48 | 42.96 | 645.5 | 449.07 | 291.43 | 203.92 | 113.68 | 73.29 | 61.71 | 55.08 | 40.11 | |
| 29 | 19-04-2016 15:53 | | Up | 1 | 157.73 | 13.46006 | 77.23409 | 23 | 130.72 | 610.27 | 43.14 | 41.6 | 29.17 | 42.54 | 647.93 | 431.97 | 290.25 | 203.4 | 115.96 | 73.26 | 57.58 | 54.35 | 39.45 | |

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# 4. Ground Penetrating Radar (GPR)

## 4.1 General

Ground Penetrating Radar (GPR) is a geophysical method that uses radar pulses to image the subsurface so that it can be used for identification of the pavement layers thicknesses. GPR is non-destructive equipment and provide layers internal details without the need for breaking the pavement. The GPR system of PRAMC provide complete assessment of road conditions, such as:

- Pavement thickness measurement;
- Surface, base and sub-base road course assessment;
- Detection of cavities, voids and delamination.

GPR is mounted on the front side of vehicle in which FWD is in-vehicle mounted. The GPR system which is used under PRAMC is shown in Figure 4-1.

**Figure 4-1: GPR setup on Vehicle**

The GPR system comprises of the following components

| Sr. Nº | Component | Purpose |
|---|---|---|
| 1. | Distance Measurement Instrument (DMI) | a distance measurement device |
| 2. | Global Positioning System | For recording the spatial coordinates |

| | | |
|---|---|---|
| 3. | Horn Antennas | For detecting the depth and alignment of layers |
| 4. | Digital Antenna Driver(DAD) Controller | to control the operation of antennas and record the DMI(encoder) readings |
| 5. | Rugged Laptop | For operating GPR through DAD controller |

### 4.1.1 Digital Antenna Driver (DAD) Controller

The Control unit is the brain centre for the GPR system and is responsible for coordinating the operation of the other components of GPR. It is the control unit responsible for directing the antennas and digitalising the acquired radar data.


**Figure 4-2: DAD Controller**

### 4.1.2 Horn Antennas and Dual Frequency Antenna

GPR collects the data using 4-channel system with each channel is having one frequency and these frequencies are generated by separate antennas but all antennas are controlled by single control unit in the vehicle. Antennas does the work of transmitting radar signals and receiving the reflected waves. The frequency of the antennas used are 2GHz, 1GHz, 900MHz and 400MHz (Figure 4-3 and Figure 4-4).

**Figure 4-3: Horn Antenna**


**Figure 4-4: Dual Frequency Antenna**

### 4.1.3 Distance Measurement Instrument (DMI)

The Encoder is generally a mechanical device, such as a wheel, that is used to measure distance along the target area and initiates a triggering pulse for the radar signal at predetermined distances. In some cases, a GPS is used in the Encoder to determine location and distance for triggering.

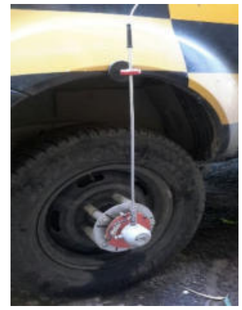

**Figure 4-5: DMI**

### 4.1.4 Ratchet Belts

The height of the antennas are adjusted by tying the fibre glass frame to the vehicle body with the ratchet belts. These belts are non-metallic in nature, and it is mandatory to use only non-metallic belts, because if metal belts or other ropes are used those metallic particles /body will interfere with the radio waves of the GPR Antennas which in turn will affect the quality of the information acquired.

**Figure 4-6: Ratchet Belts**

### 4.1.5 Data Acquisition Software

K2-Fastwave acquisition Software is used for collecting the data in the field. This software is installed on a Notebook Computer which is supplied along with the GPR system.


**Figure 4-7: Data Acquisition Software-Start up Screen**

### *4.1.6 Rugged Laptop*

The K2-Fastwave acquisition software is installed on a Notebook Computer, which is dedicated to the specific phases of setting up, acquiring and saving radar data. The data logger is used for controlling the operations of GPR, to acquire and store the data collected in the field. The data acquired through will be further processed using the GRED HD software.

**Figure 4-8: Rugged Laptop**

The configuration of the data logger used in GPR survey is:

- Operative system: Windows 7
- Processor: Intel i5 mobile tech
- RAM: 4GB Ram
- Hard Disk: 500 GB HDD, shock-damped
- Lan: 100 Base-TX/10 BASE

**Note:** No communication software of the type Firewall, Wi-Fi or Antivirus protection may be installed on the computer; these types of software enter into conflict with the acquisition software.

## 4.2 Setup of Acquisition Software

The K2_FW acquisition software is used to manage the phases of radar acquisition and to review the data acquired directly on site. The DAD Fast Wave has an “Interlaced” acquisition mode that allows the acquisition of double channels almost simultaneously, this permits an acquisition velocity twice as fast as normal K2_FW systems.

The operative phases of the K2_FW acquisition software occur in the following sequence:

- Start up the K2_FW software
- Choose the configuration
- Set up the calibration
- Choose the survey
- Set the acquisition parameters
- Acquire the radar data
- Review the data

Please refer to *GPR user manual* for more details about the above mentioned phases.

## 4.3 Daily Checks

Check the functional status of the system with the reference of spy lights representing the radar (RADAR), battery (BATT), and acquisition speed (SPEED) and acquired sweeps (SWEEP). The system function spy lights

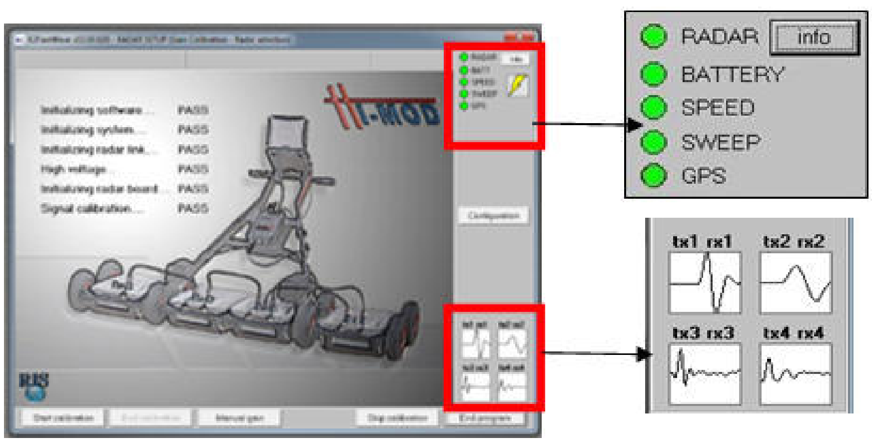


**Figure 4-9: Spy lights**

When the spy lights are coloured

- White: this means the system is not active
- Green: this means the system is functioning correctly
- Red: this means the system is not functioning correctly

Check all the antennas connected in the order and are working, any antenna displaying the straight line instead of wave form needs the checking of connections

- The list of tests to be pass as shown in Figure 4-9, if any fail in the tests please check the connections

- Order of the antenna positions which are to be connected
  - 400 MHz: TX1 RX1,
  - 900 MHz: TX2 RX2,
  - 2000 MHz: TX3 RX3,
  - 1000 MHz: TX4 RX4

## 4.4 Survey Procedure-GPR

### *4.4.1 Calibration*

This paragraph describes the procedure used to calibrate the parameters used in the real- time processing of radar data.

- Press the Start Calibration button shown in Figure 4-9 to view the window shown in Figure 4-10, then perform the automatic calibration procedure by moving the antennas across the surface to be scanned for a distance of at least one meter.

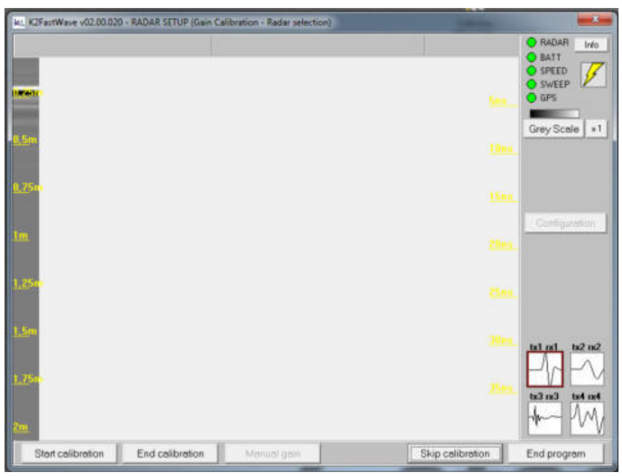


**Figure 4-10: Calibration is underway**

- Once the Calibration Gain is completed, Survey Details window will appear Automatically as shown in Figure 4-11, the Naming is to be given for the survey and click on **NEW ACQUISITION**
- For Resuming the acquisition selected road from the list of surveys appearing and click on **RESUME ACQUISITION** as shown in Figure 4-11.

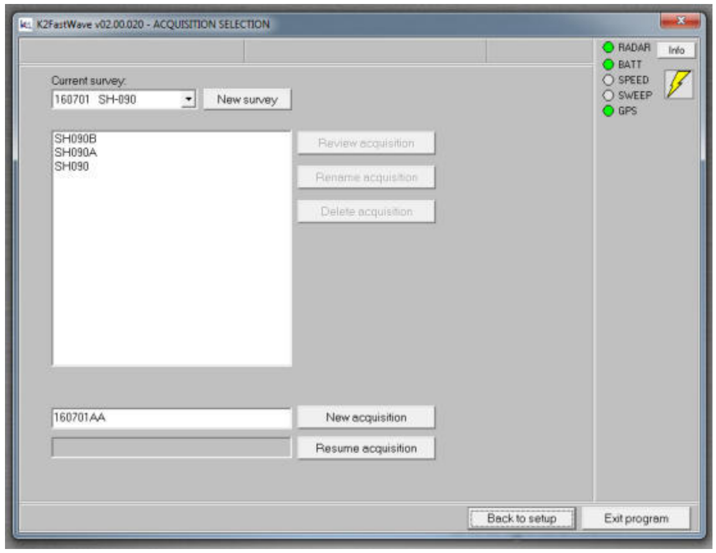


**Figure 4-11: Acquisition Selection window**

- After competition of the survey click on end acquisition which automatically saves the collected data as shown Figure 4-12 and stored in the Directory **C:\K2\MISSIONS** (with the file name the data acquired).

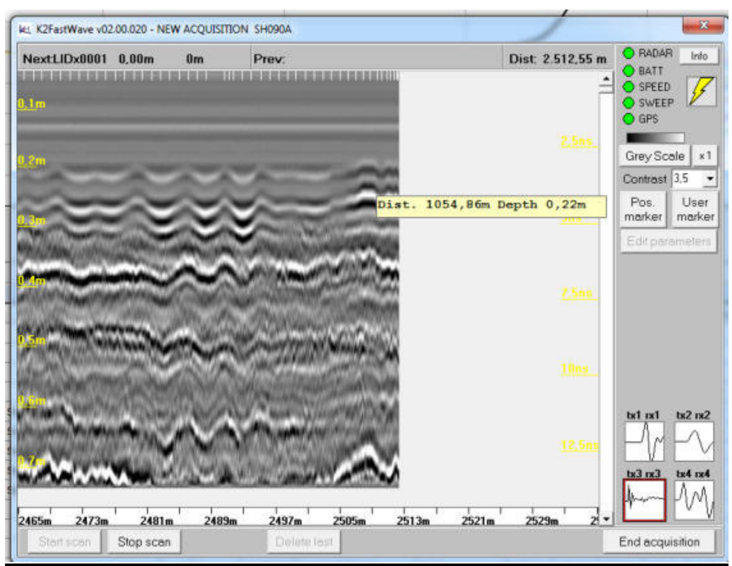


**Figure 4-12: Acquired Data**

### 4.4.2 Sampling Interval

GPR is an automatic, continuous test that gives the details of the pavement layers. The pavement layers details at the point of deflection measurements will be collected. However, as GPR is an automatic and continuous test, the pavement layers details of the road sections irrespective of the FWD intervals will be captured for the entire length of the homogeneous sections.

### *4.4.3 Procedure of Data Collection*

GPR collects the data using 4-channel system with each channel is having one frequency and these frequencies are generated by separate antennas but all antennas are controlled by single control unit in the vehicle. The frequency of the antennas used are 2GHz, 1GHz, 900MHz and 400MHz. The depth of penetration of the waves in to the ground is inversely proportional to the frequency of the antenna. Using the GPR, the pavement depth up to 1.5m can be covered. GPR referencing will be done by either GPS and/or by DMI (chainage) and the analysis software will provide the results in the spreadsheet which comes along with the GPR software. The GPR analysis of the data is typically interactive and semi-automatic.

## 4.5 Test Pit

Upon collecting the field data the GPR results are interpreted with reference to the control locations (where the asphalt thickness and pavement thickness details are known). The existing pavement layers and thicknesses information will be collected through secondary sources of PWD records of maintenance history. In the absence of such secondary information, the existing pavement layers information will be collected through primary surveys by excavating test pits.

### *4.5.1 Sampling Interval*

Test pits will be dug 1 in every homogeneous section. The length of the homogeneous section vary depending the inventory and condition and other characteristics of the road.

### *4.5.2 Data Collection*

A test pit of 0.6mX0.6m will be excavated at the outer edge of the outer lane of the pavement in the earthen shoulders exposing pavement layers sufficiently to note down the pavement layer thickness and pavement material type. After collecting the necessary details from the test pit, it will be filled back with suitable materials and compacted properly so that it will not create any safety hazard to the traffic. At each test pit, the number of layers observed, thicknesses of the layers, pavement material type, and location of the test pit will be recorded.

## 4.6 Items carried for Surveys

For performing the GPR test and to dig the test pits, the following items will be carried to the field.

**Table 4-1: Items carried for GPR and Test Pit Surveys**

| Sr. No | Description | Remarks |
|---|---|---|
| 1. | GPR Equipment | For collecting pavement layers information |
| 2. | Data Logger ( Laptop) | To collect the data in the field, operation of GPR, processing of the data |

| Sr. No | Description | Remarks |
|---|---|---|
| 3. | Shovel | For Excavating test pit |
| 4. | Crowbar | For Excavating test pit |
| 5. | Mechanical Kit | To mount Fibre glass beams |
| 6. | Digital Camera & Charger | to collect photos of test pits |
| 7. | Internet Dongle(With Minimum 3G Capability) | for the Remote Support |
| 8. | Mobile phone with charger | For communication |
| 9. | Pens / Pencil | For recording the remarks |
| 10. | Note Book / Note Pad | To record the survey status |
| 11. | Highlighters | For marking on the maps |

### 4.7 Analysis of Data

After the data collection the data will be analysed to assess the pavement layers, composition, and thicknesses. The procedure of analysing the GPR data is provided in the *GPR Manual.*

## Annexure1
## Survey Log - ROMDAS

| Survey Date | Road ID | Kiometerage | | Survey Length (km) | Name of .rbf file | Equipment Related | | | Remarks/ Observation | Signature of Operator |
|---|---|---|---|---|---|---|---|---|---|---|
| | | From | To | | | Issues | Possible Causes | Issue Resolution | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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# Annexure2
# ROMDAS
## Typical images for visual Condition Rating

**Cracking:**

Cracking will be measured in percent of surface area.

Very Good (<5%)

Good (5-10%)

Fair (11-20%)

Poor (21-30%)

Bad (>30%)

**Ravelling:**

Ravelling will be measured in percent of surface area.

Very Good (0%)

Good (1-5%)

Fair (6-10%)

Poor (11-30%)

Bad (>30%)

**Potholes:**

Potholes will be measured in percent of surface area.

Very Good (0%)

Good (0-0.1%)

Fair (0.1-0.5%)

Poor (0.6-1%)

Bad (>1%)

**Patching:**

Patching will be measured in percent of surface area.

Very Good (<2%)

Good (2-5%)

Fair (6-15%)

Poor (16-30%)

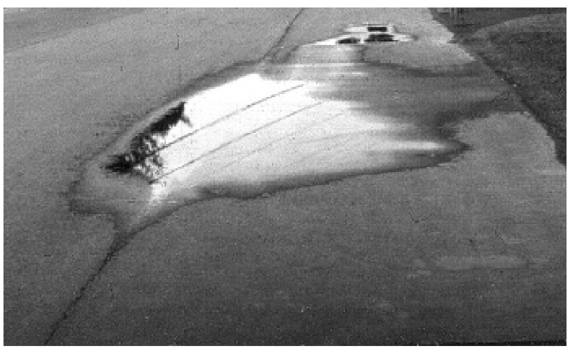
Bad (>30%)

**Depressions:**

Depressions will be measured in percent of surface area.

Very Good (0%)

Good (0-1%)



Fair (1-2%)

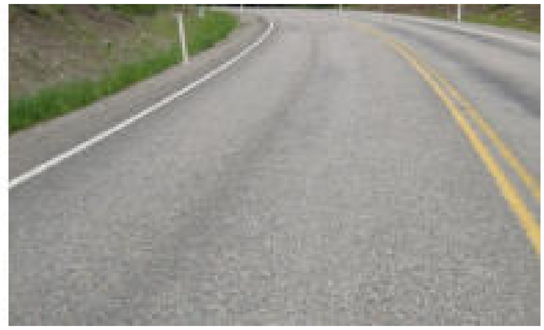
Poor (3-5%)

Bad (>5%)

**Bleeding:**

Bleeding will be measured in percent of surface area.

Very Good (0%)



Good (<5%)

Fair (5-10%)

Poor (10-30%)

Bad (>30%)

# Annexure3
# (FWD)
## Survey Log Details - FWD

| S. No | Date | Road No | Survey File Name | Road Name | Chainage in Km | | Length Surveyed in Km | Direction of Survey | Temperature (In Ground) in Centigrade | Temperature @ Chainage in km | Core Data Collected Chainage | Core Details | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | From | To | | | | | | Layer 1 | Layer 2 | Layer 3 | Layer 4 | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

## FWD machine Maintenance and Repair Summary

| Date | Odometer | Problem Description | Description of Maintenance | Performed By | Cost | | |
|---|---|---|---|---|---|---|---|
| | | | | | Labour | Parts | Total |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
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## FWD DMI Calibration

Date (DD-MMM-YYYY) ___ ___ - ___ ___ ___ - ___ ___ ___ ___

Section Length (feet) ___ ___ ___ ___

New Calibration Factor (Counts per km) ___ ___ ___, ___ ___ ___

Performed By: ______________________________

Government of Karnataka
Public Works Department

# ROAD DATA PROCESSING AND QUALITY ASSURANCE PROCEDURES

# TABLE OF CONTENTS

# LIST OF TABLES



# LIST OF FIGURES

# ABBREVIATIONS

| | |
|---|---|
| CDT | Construction data |
| CRN | Core Road Network |
| DAD | Digital Antenna Driver Controller |
| DAPS | Deflection Analysis of Pavement Structures |
| FWD | Falling Weight Deflectometer |
| GPR | Ground Penetrating Radar |
| GPS | Geographical Positioning System |
| GRED HD | Georadar Data Elaboration High Density |
| KRAMS | Karnataka Road Asset Management System |
| MDR | Major District Road |
| MHz | Megahertz |
| NH | National Highways |
| PRAMC | Planning and Road Asset Management Centre |
| PWD | Public Works Department |
| $RMS_{err}$ | Root Mean Square error |
| ROMDAS | ROad Measurement Data Acquisition System |
| SH | State Highway |
| USB | Universal Serial Bus |
| UTC | Coordinated Universal Time |

# 1. Introduction

## 1.1 Introduction

Planning and Road Asset Management Centre (PRAMC) is responsible for determining the annual maintenance requirements of the road network under jurisdiction of PWD. Currently PRAMC is focussing on the preliminary Core Road Network (CRN) of 25,000km that consists of National Highways (NH), State Highways (SH), and Major District Road (MDR). On this CRN various kinds of road data including road inventory, condition, pavement strength, pavement rut, pavement roughness and video surveys are being collected with the aid of advanced technological equipments. The equipments which are being used in road data collection are (1) ROad Measurement Data Acquisition System (ROMDAS) (2) Falling Weight Deflectometer (FWD) (3) Ground Penetrating Radar (GPR). As the data being collected is of large volume, utmost care shall be exercised during data collection, processing, validation and compilation.

## 1.2 Scope of this Document

The R*oad Data Collection Procedures* document provide the guidelines about the road data collection procedures, whereas this document provides the procedures of the data processing, validation, and compilation of data. This document presents a logical system which will facilitate the processes of data checking, data processing, validation and compilation. This document targets to highlight the procedures for

- Receiving data from field teams;
- Checking of raw data for its completeness;
- Data processing;
- Validating processed data;
- Compiling the data in the predefined formats for further uses.

# 2. Data Processing- ROMDAS

## 2.1 Survey Data Submission

After completion of the field survey the field data shall be submitted to the office staff at regular intervals e.g., weekly or fortnightly or whenever possible, by using portable external hard disks. At the time of submission the following data shall be submitted:

- Raw (ROMDAS) survey files (.rbf);
- Video files (.avi);
- Survey log sheet containing the details of the surveyed length;

The summary of the details received from the field staff shall be maintained by the office staff in a log file. A sample log file is given in Table 2-1.

**Table 2-1: Data receiving Log file**

| Survey Date (dd/mm/yyyy) | Link ID | Link Description | Starting From | Ending At | Length (km) | Number of RBF Files | Number of Video Files | Survey IDs | Data handed over date (dd/mm/yyyy) | Data Submitted by (field staff name) | Data received by (office staff name) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

The office staff shall review the completeness of the details provided by the field staff, and can reject the data if any of the required information is missing, and may also suggest the field team to do resurvey.

## 2.2 Data Receiving

### 2.2.1 *File structure*

Any data collection activity requires a systematic data filing, to ensure that the appropriate and relevant data is available to all the staff working on the project at the ease. The file structure which is followed for storing the data in the project server is as shown in Figure 2-1.

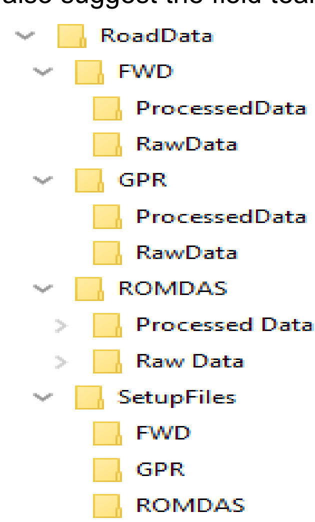


**Figure 2-1: File Structure**

### 2.2.2 File Naming Convention

The file names shall be selected in such a way that they are self-explanatory. An index document shall be created to describe the files or contents of the file.

## 2.3 Processing of Raw Data

All survey data is recorded in a binary format file (rbf). These files can be processed using ROMDAS software to produce Microsoft access i.e., .mdb files. The file names for the processed files are taken as the name from the **Survey File** field in the Survey setup log. For example, a survey file of SH16 would results in the file SH16.mdb.

The step by step process of processing the .rbf files to .mdb files is as mentioned below.

- Copy the .rbf file in the C:\ROMDAS\Survey Data\Data folder in the computer in which ROMDAS software is installed
- Open ROMDAS software and select *Data Processing* option which prompts to select the raw .rbf file

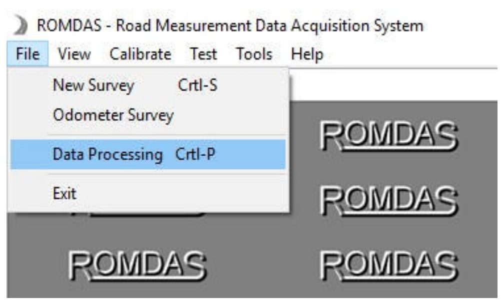



**Figure 2-2: Selecting *Data Processing* Option- ROMDAS**

- Open the .rbf file from the directory C:\ROMDAS\Survey Data\Data for processing

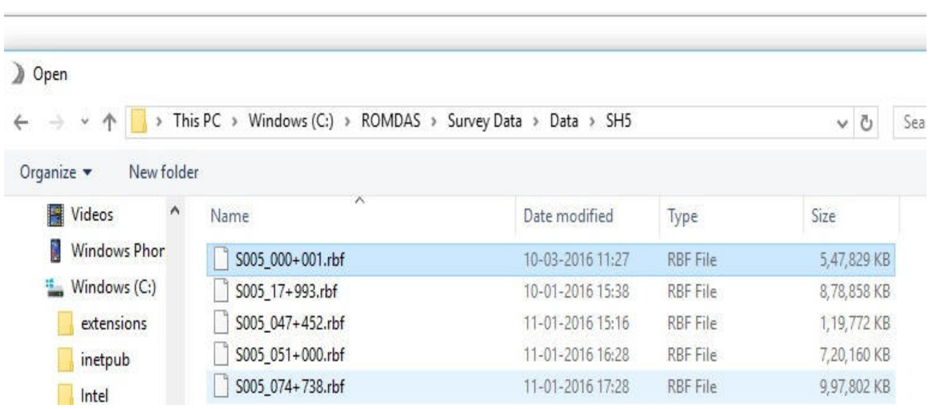



**Figure 2-3: Selecting raw file for processing**

- Add the .rbf files to ROMDAS software

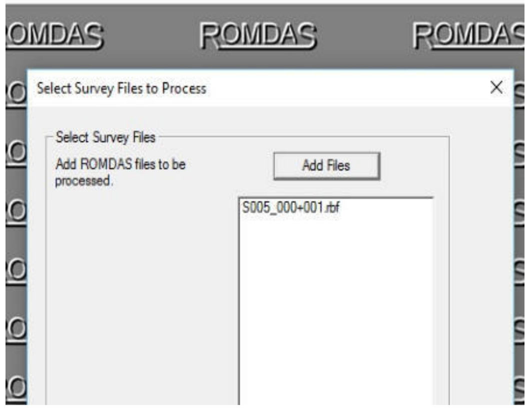
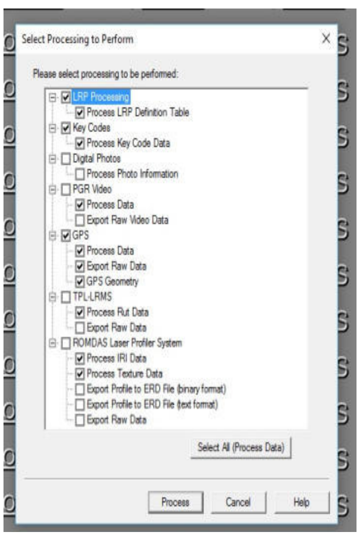



**Figure 2-4: Adding files for Processing**

- On the basis of the data collected, select the applicable data items for processing and click on *Process,* which will commence the processing of data and it time taken for completing the processing depends on the size of the file and number of data items included in processing



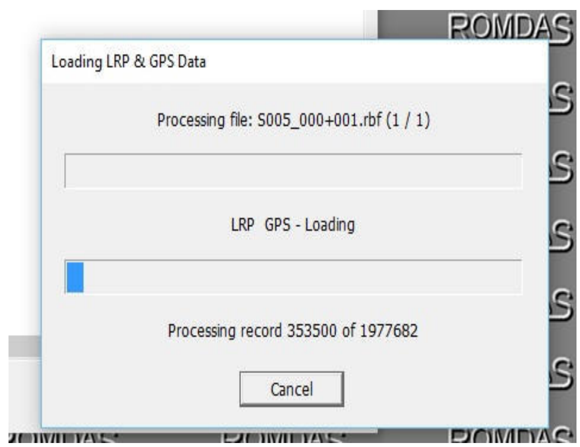




**Figure 2-6: Selecting applicable data for processing**

**Figure 2-5: Data Processing underway**

- After processing is completed, .mdb files will be created at the same file location where the .rbf file is located.

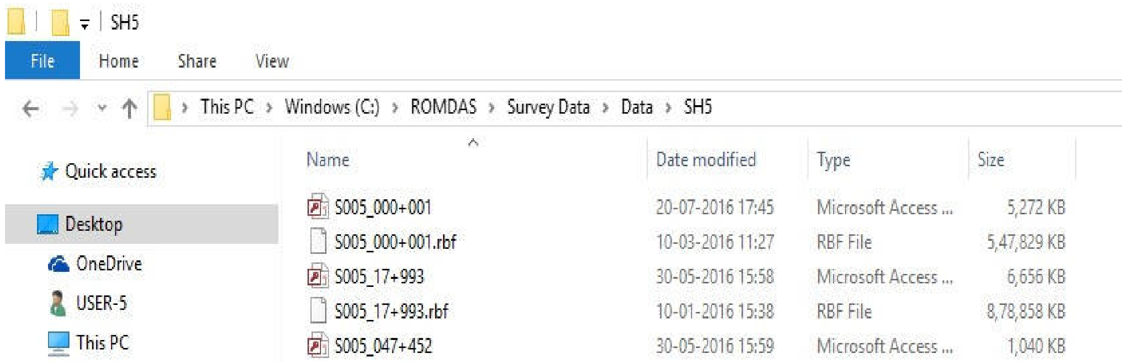



**Figure 2-7: Microsoft Access (.mdb) files created**

## 2.4 Validation of Processed Data

After processing the field data the data shall be validated. During this validation the following items will be audited and confirmed;

- Survey data is available for the entire link;
- If any missing information in Inventory and condition data;
- Random checking of the inventory and condition data with the videos;
- Acceptable video images and no gaps in video files;
- No significant gaps in GPS data;
- Anomalies in the collected data;
- Mismatches in the chainages across various data tables of the same link.

During the above validation exercise if it is found that any data is of not acceptable quality, then reprocessing of the data shall be carried out. If no acceptable results are obtained after the reprocessing then resurvey of the respective survey sections is required.

## 2.5 Data Compilation

After completing the data validation, the finalised data will be compiled and submitted for the necessary further uses. The processed data shall be submitted as follows:

- As per the Formats, given in Annexure A;
- Video files in AVI format;

# 3. Data Processing- Falling Weight Deflectometer (FWD)

## 3.1 General

Under PRAMC, the pavement deflection data collected by Falling weight Deflectometer (FWD) is analysed using Deflection Analysis of Pavement Structures (DAPS) back calculation software. This is a rapid, accurate and reliable method for performing back-calculation of deflection results to find out the layer stiffness modulus using a singular decomposition technique.

## 3.2 Theoretical Background

The DAPS algorithm solves for both a two layer elastic system and the thickness of subgrade, or a three layer elastic system and the thickness of subgrade. A least square solution process is applied, employing all the measured deflections as parameters characterizing the bowl.

A rigid base beneath the subgrade is assumed ('bedrock'). This is an accepted method, to some extent, to allow for known effects of non-linearity within the subgrade soil. The rigid base depth is used as an unknown to be solved for, along with the layer modulus.

Seed values for the AC and subgrade stiffness's are obtained from equations published by Thompson (1989), using deflections d0 to d3. These are used to generate trail values of the parameters characterizing the bowl (i.e. the deflections). If a granular base is assumed to be present, the granular base resilient modulus seed value is estimated by empirical relations (Thompson, 1982). If a three-layer system without granular base is to be solved, the subgrade E estimate can be used for the base layer also. An arbitrary fixed initial trail value of subgrade thickness is employed, viz. 7m.

As described so far, it is evident that there are 7 known parameters, and either 3 or 4 unknowns, viz. 2 E's and 1T, or 3E's and 1T. Since there are more parameters than unknowns, an over-determined set of simultaneous equations can be set up relating changes in the unknowns to changes in the deflections by means of a matrix of partial derivatives, dpi/dUj, where p are the deflections and U are the unknowns (either E values or thickness value).

A least squares solution to these simultaneous equations is obtained by an iterative process using, at each iteration, a solution of the over-determined equation set by the Singular Value Decomposition technique (Press et al., 1986).

The difference between the computed deflections based on the initial unknown's estimates (seed values), and the measured deflections are hence minimized by the following procedure for updating the unknowns:

$$P_k a_k = r_k$$

where:

Pk = the kth iteration of the matrix of partial derivatives dpi/dUj of the parameters p1, I=1 to 7, with respect to the 'unknown' layer modulus and thickness Uj, j=1 to 3 or 1 to 4.

ak = the kth difference vector, which is the differences Uj,k+I –Uj,k between the modulus/thickness used in the Pk matrix and the new modulus/thickness Uj,k+I to be used in the (k+1)th iteration.

rk = the residual vector of differences between the most recently computed parameters and the parameters represented by the measured deflections.

In the above equations, the partial derivatives comprising the P matrix are estimated numerically, by Elastic Layer analysis. At present, no limits are applied to E values generated by the minimization procedure.

This back-calculation procedure is considered to be suitable for:

- Full depth asphalt concrete (AC)
- Conventional (AC surface plus granular base)
- AC + high-strength stability base (HSSB)
- PCC over granular base

### 3.3 Validation of the Acquired Data

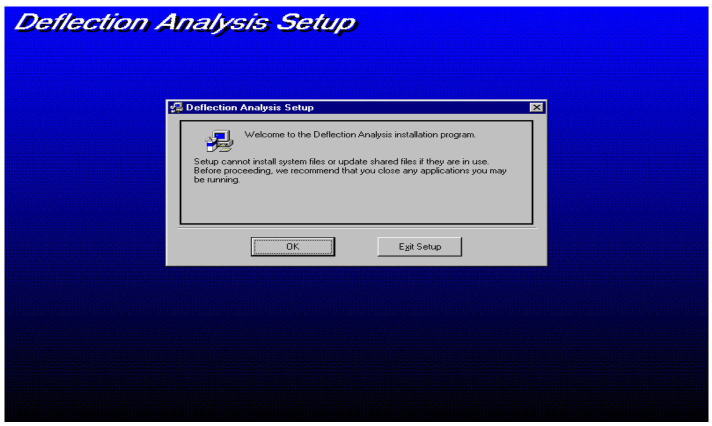
After collecting the data from the field, prior to carrying out further processing the following validation checks shall be performed

- The values of deflections should be in descending order form geophone D1 to D9;
- If any of the deflection from the sensor D1 to D9 is missing / showing more value than its preceding geophone value, such values should be corrected with the average reading of the test data from the remaining Drop tests conducted at the same location;
- The first row of Deflections should not be blank. In case of any missing in data the complete drop test is omitted or the immediate drop in the same location is to be used for the back calculation;
- If the First Geophone Data/ majority of the Geophones data collected is invalid/Missing for all the drops at a Location, such data should not be processed further.

## 3.4 Installation of DAPS Software

The DAPS program is supplied on a single CD-ROM. The user runs the setup.exe program using normal windows execution (e.g. from run menu a:\setup.exe) and then follows the instructions given by the software.

The setup creates a default directory of c:\daps and c:\daps\data1. The data directory is the default data directory for storing deflection data for analysis. The user can change this directory if necessary along with the program directory during the installation process. Following the installation it is recommended that the user restarts the computer to ensure that all setting changes have taken place.

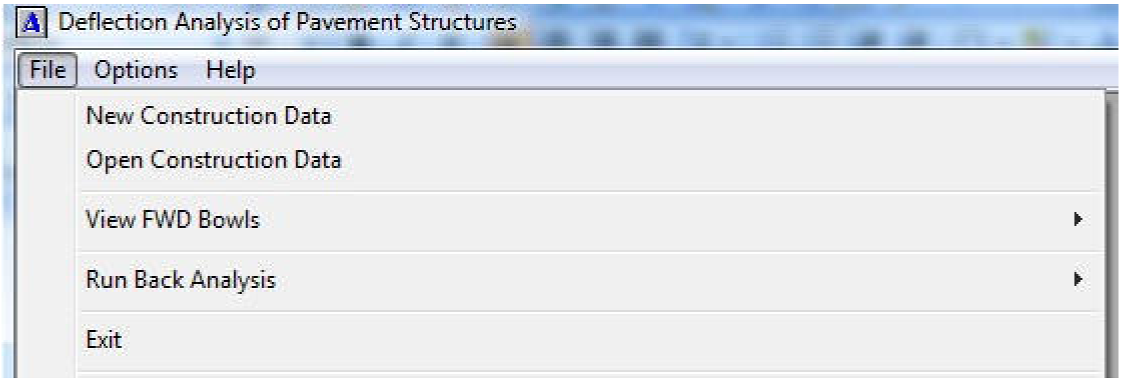



## 3.5 Program Use

The user runs the program from the Start-Program menu or using other standard window methods and then starts by selecting the file menu as illustrated. The file menu enables the user to choose an area to work in. The choices are illustrated and are as follows:

- New Construction Data
- Open Construction Data
- View FWD Bowls
- Run Back Analysis
- Exit

Each of these areas will be considered in detail in the following pages.




## 3.6 Construction Data

Pavement construction information must be defined to enable back calculation. This is done via the creation of a construction information file. The file should have the same root name as the FWD data file and would be normally located in the default directory c:\daps\data unless otherwise specified by the user (Figure 3-1).

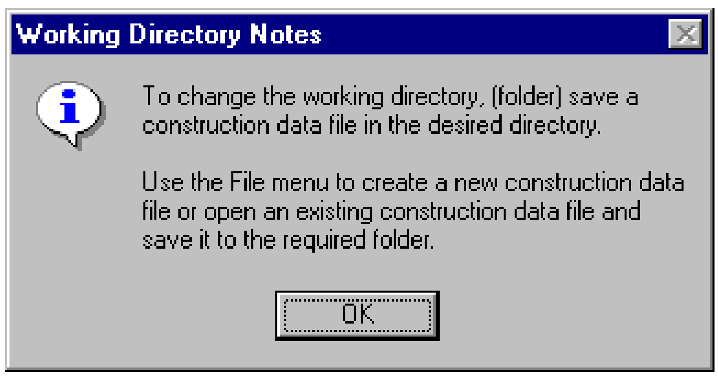



**Figure 3-1: Working Directory Notes- DAPS**

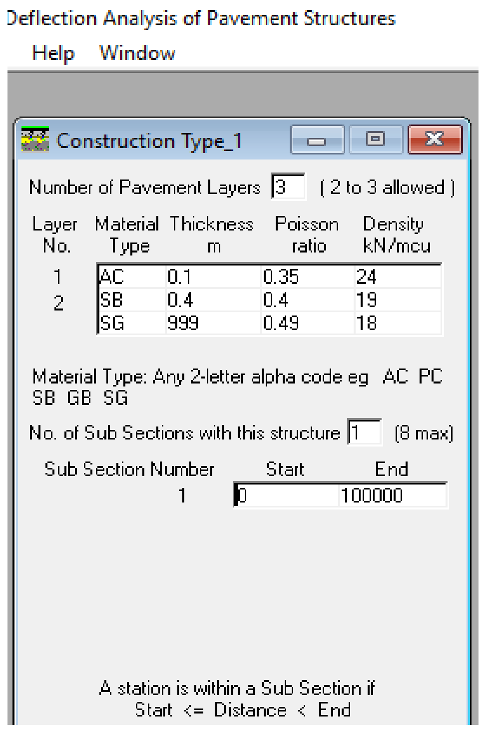



**Figure 3-2: Example of Pavement Construction Types**

The pavement construction information can be defined for various lengths of the pavement by reference to the location numbers. In the example given (Figure 3-2), three construction types have been defined for the FWD data file. The user must define a length of pavement associated with each construction type. The information stored will be as follows:

Material Types:

- AC – Asphalt Concrete
- PC – Portland Cement
- GB – Granular Base
- SB – Granular Sub-base
- SG – Subgrade

Poisson's ratio must be less than 0.5. Thickness and density inputs are in metric units. When the user has completed the data entry in this area he uses the *Save* or *Save As* file commands to store the file. An alternative to starting a new construction information file is to use the data in an existing file by opening and then use the *Save As* command to a new file name after completion/modification of data.

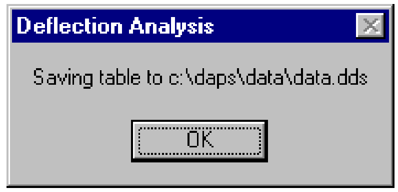



**Figure 3-3: Saving Construction Data**

## 3.7 View FWD Bowls

When selecting the menu option *View FWD Bowls* the user is presented with the form as illustrated in Figure 3-4. Data files in the working directory are listed under the data item in the grid. The program recognizes most common FWD file formats, including one EXCEL spreadsheet format. Initially, all other information items are blank. Hitting the Summarize button fills in this information. This summary can be saved to the hard disk. The data is stored in the file *data.dds* and is illustrated below.

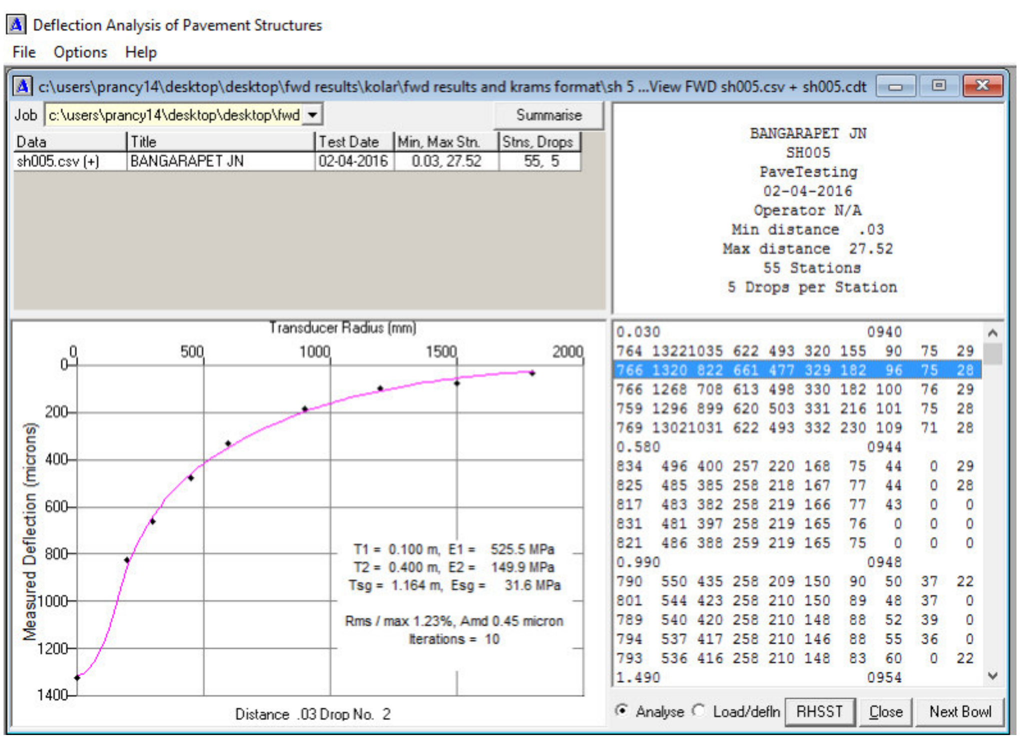



**Figure 3-4: Option *View FWD Bowls***

This process determines the number of deflection bowls in the data file and allows the user to review the distance/station information to be reviewed with ease.

**<u>The plus symbol next to the data filename indicates that a CDT (construction data) file has been completed</u>** (Figure 3-5) which is necessary to perform the back-calculation. A box towards the upper right corner of the screen contains general information in the file. Title, test date, distance information, number of stations and drops per station are displayed in the grid.

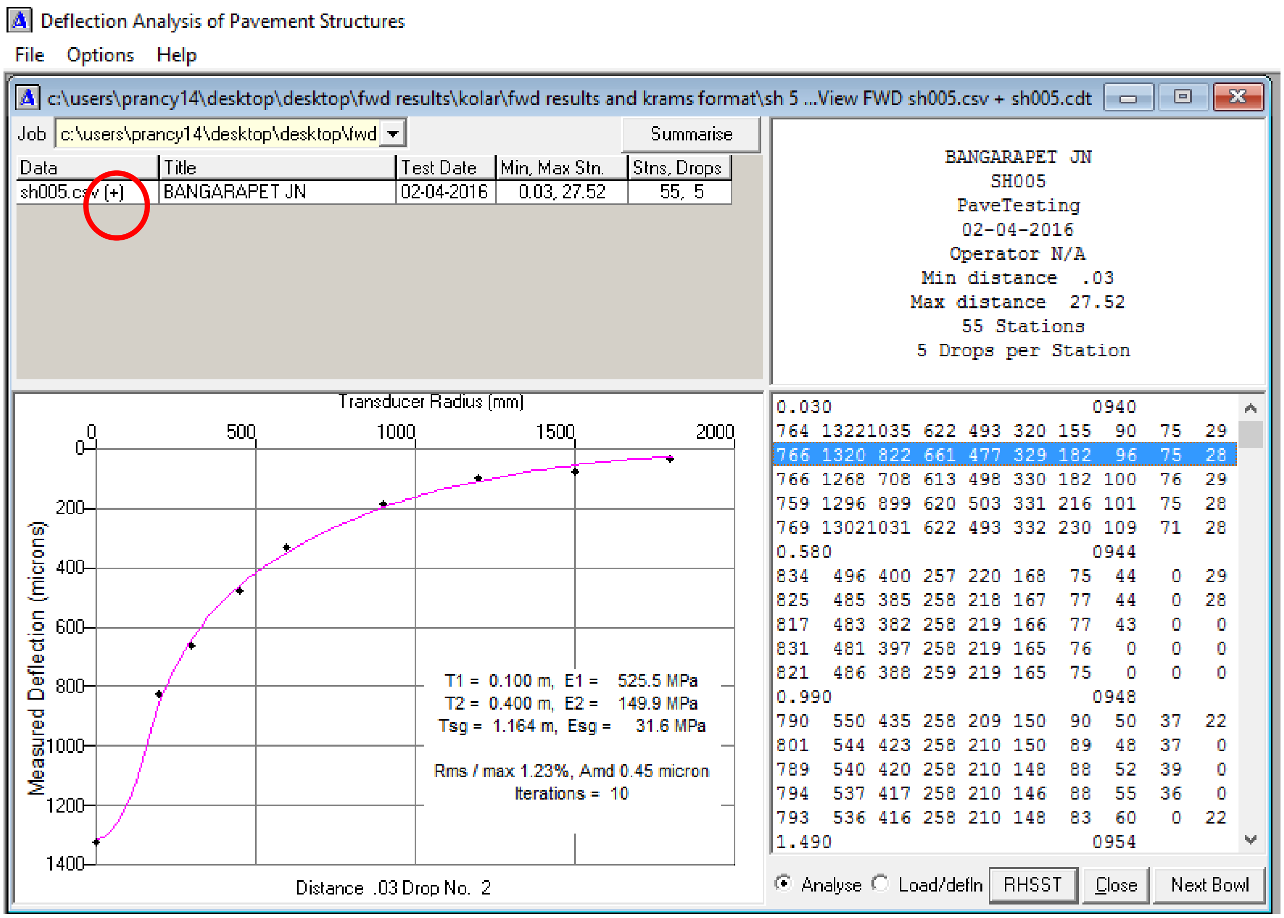



**Figure 3-5: Indication of Construction File completion**

Single data points can be analysed by interactively clicking on a deflection bowl (providing a CDT file has been made). Information displayed on the deflection bowl graph includes the layer stiffness and the calculated stiffness for each pavement layer. The thickness of the soil layer is the calculated thickness to an assumed rock foundation. The statistic RMSerr/Max

(Root Mean Square error divided by Maximum Deflection) is also given. A RMSerr/Max of less than 4% is considered as a satisfactory deflection bowl match. It is recommended that users use this feature to inspect the data files and determine which model most accurately fits the back-analysis.

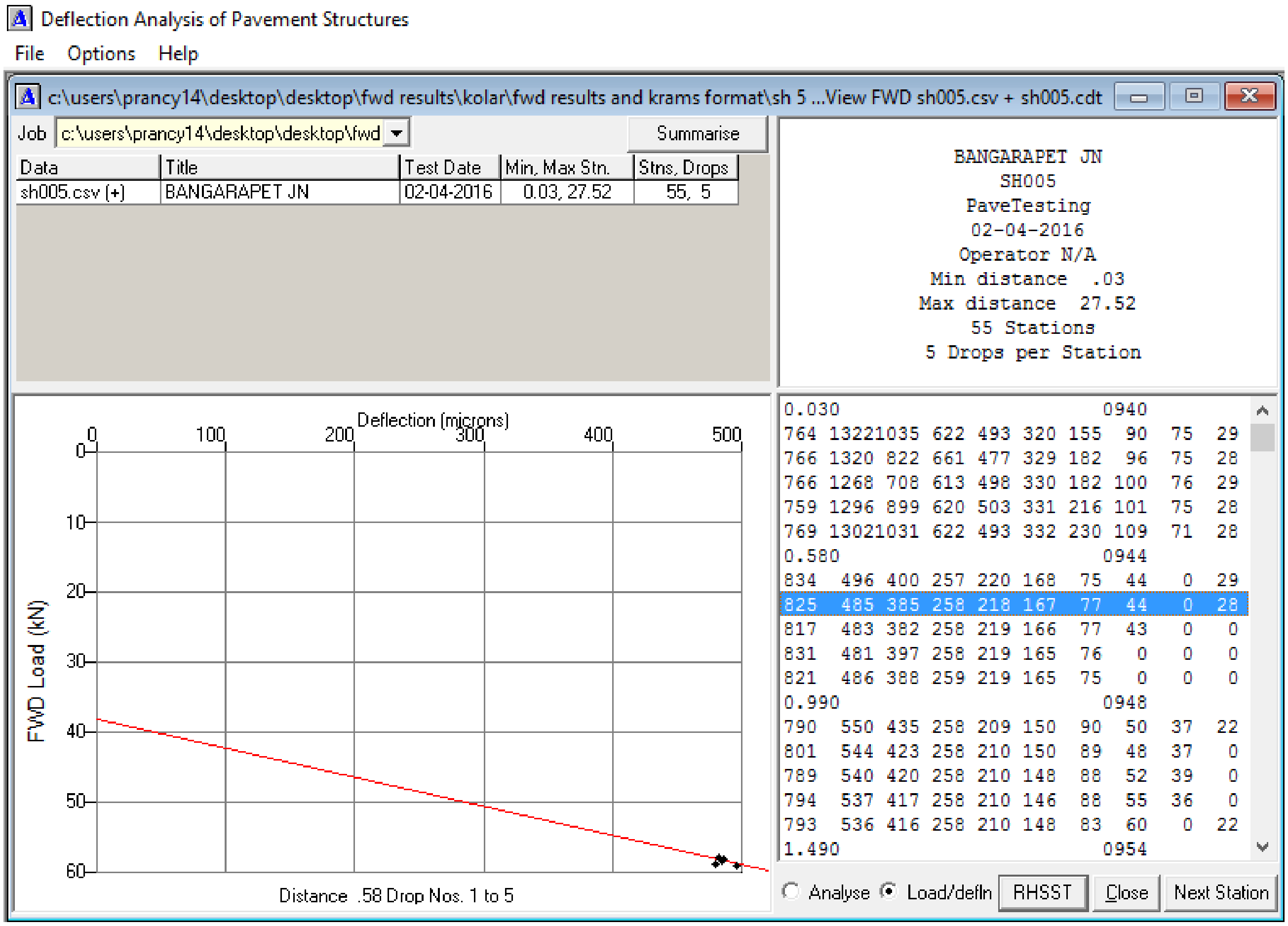



**Figure 3-6: Indication Graph Showing Load/Deflection**

## 3.8 Processing of FWD Data

A file which can be processed is indicated by a (+) symbol next to the data file name. The file is selected and processed by selecting the "run" button. Information is updated as the analysis takes place in the display grid. The modulus of the layers are displayed (E1 to E3) along with the thickness of the soil layer to bedrock (Sthk), the calculated horizontal strain (tensile) at the underside of the bound layer (epsH) and the vertical strain at the top of the soil layer (epsV). In addition the %RMS (Root Mean Square error divided by Maximum Deflection) is given in the last column. As discussed earlier a %RMS error of less than 4% is considered as a satisfactory deflection bowl match. The summary window (middle right) indicates general statistical information on the analysis such as number of bowls successfully analysed. The user can save the results by clicking on the *Save Results* button. In addition, the user is able to review the data and make any changes to the construction information, if required, and rerun the analysis. The file, when saved, is stored in a *BLS* file that is formatted to enable easy import into a spreadsheet for further manipulation and/or analysis. The order of the data in the .BLS file matches the columns given in the Figure 3-7 are shown in Table 3-1.

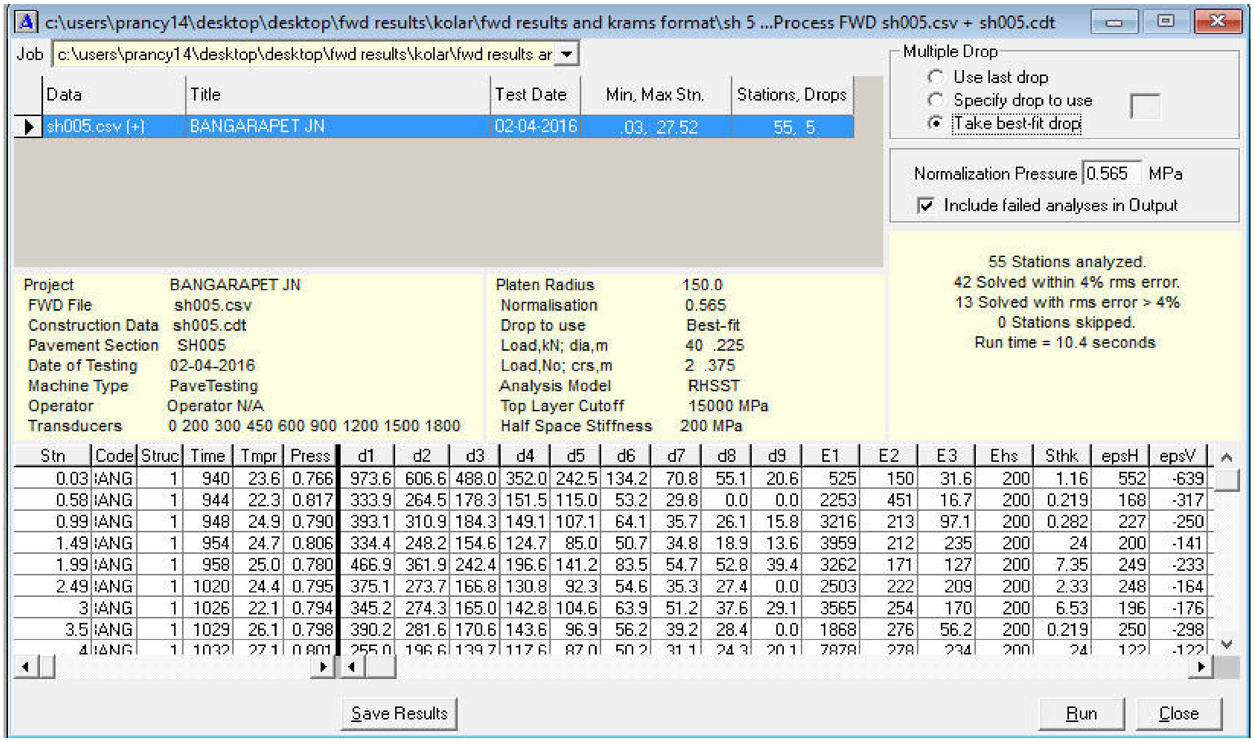



**Figure 3-7: Back Calculation Results**

**Table 3-1: .BLS file columns Description**

| Column # | Description |
|---|---|
| Stn | Station number |
| Code | If entered a code is shown |
| Struc | A code number for a structure |
| Time | If entered a time will be displayed |
| A.Tmpr | Air temperature |
| S.Tmpr | Surface Temperature |
| Press | Pressure on loading platen |
| d0 | Deflection of 1st sensor |
| d1 | Deflection of 2nd sensor |
| d2 | Deflection of 3rd sensor |
| d3 | Deflection of 4th sensor |
| d4 | Deflection of 5th sensor |
| d5 | Deflection of 6th sensor |
| d6 | Deflection of 7th sensor |
| d7 | Deflection of 8th sensor |
| d8 | Deflection of 9th sensor |

| Column # | Description |
|---|---|
| E1 | Stiffness modulus of top layer |
| E2 | Stiffness modulus of second layer |
| E3 | Stiffness modulus of third layer |
| Ehs | Stiffness modulus of half space |
| Stkh | Thickness calculated to bed-rock |
| epsH | Calculated horizontal strain at underside of lowest asphalt layer |
| epsV | Calculated vertical strain on top of half space (assumed soil) |
| %rms | Root mean square error of bowl fit compared to measured deflections |
| Amd µ | Absolute micron deviation of calculated bowl from fitted bowl |
| c1 | Calculated 1$^{st}$ deflection using solved values |
| c2 | Calculated 2$^{nd}$ deflection using solved values |
| c3 | Calculated 3$^{rd}$ deflection using solved values |
| c4 | Calculated 4$^{th}$ deflection using solved values |
| c5 | Calculated 5$^{th}$ deflection using solved values |
| c6 | Calculated 6$^{th}$ deflection using solved values |
| c7 | Calculated 7$^{th}$ deflection using solved values |
| c8 | Calculated 8$^{th}$ deflection using solved values |
| c9 | Calculated 9$^{th}$ deflection using solved values |

The other options on this window allow the user to use the last drop for the analysis, specify which drop to use or to use the best fit drop. If the best fit drop is selected then the software will attempt an analysis with each deflection bowl at a given location but only save the data with the lowest % RMS error. The user may also specify a normalization pressure. This adjusts all the output to a constant applied stress rather that the deviating stress that is typically found in FWD deflection data. In addition, failed output can also be included. This is a useful feature since it enables an engineer to see which deflection bowls could not be analysed. The engineer may choose other methods to estimate a stiffness modulus for these locations. Results Obtained in *.bls* format are as Shown in the Table 3-2.

## Table 3-2: Results obtained in "*bls*" format

| | B |
|---|---|
| 1 | Near Karnataka - Andra pradesh Border" |
| 2 | ,"sh-099 2016-02-28.csv" |
| 3 | tion Data,"sh-099 2016-02-28.cdt" |
| 4 | t Section,"SH-099 2016-02-28" |
| 5 | esting,"2/27/2016" |
| 6 | Type,"PaveTesting" |
| 7 | ,"Operator N/A" |
| 8 | ers,"0 200 300 450 600 900 1200 1500 1800 " |
| 9 | adius,"150.0" |
| 10 | ation,"1" |
| 11 | se,"Best-fit" |
| 12 | dia,m," 40 .225" |
| 13 | crs,m,"2 .375" |
| 14 | Model," RHSST " |
| 15 | r Cutoff," 15000 MPa" |
| 16 | on,"3/23/2016 5:17:45 PM" |
| 17 | ,"DapsVersion 1.7.6, DLL v.29" |

| | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB | AC | AD | AE | AF | AG | AH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | Code | Struc | Time | A.Tmpr | S.Tmpr | Press | d1 | d2 | d3 | d4 | d5 | d6 | d7 | d8 | d9 | E1 | E2 | E3 | Ehs | Sthk | epsH | epsV | %rms | amd µ | c1 | c2 | c3 | c4 | c5 | c6 | c7 | c8 | c9 |
| 19 | Near | 1 | 1307 | 34.7 | 39.4 | 0.578 | 842.4 | 575.5 | 438.4 | 318.7 | 240.6 | 132.2 | 75.9 | 58.8 | 50.5 | 1525 | 290 | 19.9 | 200 | 0.324 | 259 | -417 | 0.59 | 0.62 | 487.6 | 332.1 | 255.5 | 183.5 | 137 | 78.7 | 46.9 | 30.6 | 22.9 |
| 20 | Near | 1 | 1313 | 32.4 | 39.4 | 0.572 | 861.4 | 532.5 | 394.4 | 299.1 | 257.9 | 150.6 | 97.5 | 91.5 | 0 | 629 | 379 | 64.9 | 200 | 0.907 | 236 | -293 | 2.2 | 1.7 | 494.5 | 300.9 | 233 | 177.4 | 140.1 | 88.3 | 55.8 | 36.2 | 25 |
| 21 | -- | 1 | 1317 | 32.8 | 39.4 | 0.576 | 1190.2 | 841.9 | 597.3 | 447 | 358.3 | 204.2 | 141.3 | 110.1 | 0 | 1115 | 194 | 51.6 | 200 | 1.42 | 374 | -428 | 2.07 | 1.7 | 689.5 | 470.3 | 362.2 | 262.7 | 200.6 | 122.1 | 74.6 | 45.7 | 28.4 |
| 22 | -- | 1 | 1320 | 32.7 | 39.4 | 0.567 | 1411.9 | 1066.2 | 769.5 | 585.5 | 465.2 | 275.6 | 165.1 | 0 | 0 | 1120 | 188 | 11.5 | 200 | 0.651 | 383 | -677 | 2.3 | 3.4 | 806.2 | 579.7 | 462 | 344 | 261.9 | 147.3 | 74.8 | 32.5 | 10.7 |
| 23 | -- | 1 | 1323 | 32.6 | 39.4 | 0.578 | 1151.1 | 846.5 | 629.8 | 471.2 | 371.9 | 219.5 | 144.3 | 97.3 | 80.9 | 1796 | 166 | 65.3 | 200 | 2.52 | 342 | -383 | 0.93 | 0.36 | 667.6 | 480.7 | 376 | 271.9 | 207.2 | 130.9 | 86.8 | 59.2 | 41.4 |
| 24 | -- | 1 | 1325 | 32.4 | 39.4 | 0.57 | 1209.6 | 904.6 | 647.8 | 486.2 | 380.6 | 216.4 | 154.4 | 112.8 | 72.6 | 1831 | 144 | 69.1 | 200 | 3.06 | 366 | -387 | 1.36 | 0.63 | 694.1 | 500.2 | 389 | 277 | 208.3 | 130.6 | 87.6 | 61.2 | 44.1 |
| 25 | -- | 1 | 1331 | 34.4 | 39.4 | 0.602 | 766.5 | 458 | 322.6 | 255.5 | 220.1 | 128.1 | 0 | 0 | 0 | 454 | 515 | 13.8 | 200 | 0.219 | 166 | -363 | 5 | 13 | 468 | 262.7 | 204.8 | 157.8 | 124.2 | 77.3 | 50 | 35 | 27.1 |
| 26 | -- | 1 | 1334 | 33.1 | 39.4 | 0.574 | 1281.6 | 1007 | 717.9 | 539.4 | 409.4 | 215 | 107.3 | 74.8 | 48 | 2331 | 122 | 47.3 | 200 | 1.33 | 358 | -480 | 1.74 | 0.65 | 741.3 | 554.7 | 437.9 | 309.5 | 224.4 | 124.9 | 71.4 | 41.1 | 24.2 |
| 27 | -- | 1 | 1337 | 33.7 | 39.4 | 0.57 | 1388.2 | 1075 | 752.4 | 548.4 | 391.3 | 182.1 | 80.1 | 50.2 | 0 | 1978 | 115 | 28.6 | 200 | 0.686 | 405 | -622 | 1.72 | 0.32 | 795.9 | 585 | 454.1 | 310.9 | 215.7 | 104.8 | 49 | 22.3 | 11.5 |
| 28 | -- | 1 | 1340 | 32.9 | 39.4 | 0.557 | 1984 | 1437.2 | 1010.1 | 700.8 | 489 | 248 | 137.1 | 0 | 0 | 989 | 89 | 25.9 | 200 | 0.916 | 640 | -814 | 1.38 | 1.3 | 1108.8 | 774.4 | 584.8 | 393.3 | 272.8 | 133.2 | 60.5 | 23.7 | 7.3 |
| 29 | -- | 1 | 1344 | 32.7 | 39.4 | 0.56 | 1756.7 | 1244.1 | 751.9 | 541.7 | 400.4 | 280.9 | 172.4 | 141.4 | 0 | 795 | 97.8 | 63.4 | 200 | 2.98 | 652 | -503 | 3 | 1.8 | 995.5 | 648.9 | 471.3 | 312.5 | 225.1 | 134.7 | 87.9 | 60.2 | 42.8 |
| 30 | -- | 1 | 1348 | 32.8 | 39.4 | 0.57 | 1270.2 | 898.3 | 543.4 | 381.1 | 272.8 | 135.4 | 77.4 | 70.5 | 0 | 1294 | 120 | 80.4 | 200 | 0.948 | 473 | -388 | 2.5 | 1.4 | 727.5 | 478.7 | 343.5 | 216.9 | 146.5 | 77.7 | 46.5 | 30.8 | 22.7 |
| 31 | -- | 1 | 1351 | 33 | 39.4 | 0.561 | 2107.3 | 1472.2 | 1041.9 | 752.8 | 588.4 | 263.3 | 160.1 | 100.4 | 0 | 698 | 99.3 | 26.9 | 200 | 1.25 | 686 | -806 | 1.39 | 0.83 | 1183.5 | 804.8 | 609.4 | 424.6 | 309.6 | 168.7 | 87.6 | 41.3 | 16.5 |
| 32 | -- | 1 | 1355 | 32.9 | 39.4 | 0.554 | 1749.3 | 1252.9 | 809.4 | 530.3 | 362.2 | 205.1 | 117.3 | 0 | 0 | 1049 | 86.6 | 47.2 | 200 | 0.991 | 624 | -601 | 2.13 | 2.4 | 974.4 | 656.4 | 477.6 | 303.5 | 202 | 98 | 50 | 26.7 | 16.1 |
| 33 | -- | 1 | 1357 | 32.8 | 39.4 | 0.555 | 1982.5 | 1522.3 | 1059.5 | 801.7 | 568.6 | 333.2 | 201.6 | 146.4 | 0 | 1207 | 85.5 | 33.8 | 200 | 1.85 | 592 | -715 | 2.09 | 2.4 | 1111.5 | 807.8 | 628.3 | 441.4 | 322.2 | 183.3 | 106.2 | 60.5 | 33.3 |
| 34 | -- | 1 | 1400 | 33 | 39.4 | 0.562 | 1963.4 | 1444.4 | 918.3 | 606.6 | 425.2 | 225.6 | 0 | 0 | 0 | 969 | 82.1 | 20.4 | 200 | 0.541 | 677 | -912 | 2.57 | 1.7 | 1111.5 | 758.7 | 557 | 353.6 | 228.2 | 92.9 | 33.3 | 10.7 | 5.6 |
| 35 | -- | 1 | 1405 | 33 | 39.4 | 0.691 | 2080.7 | 1571.8 | 1166.4 | 846.2 | 653.3 | 364.2 | 196.8 | 0 | 0 | 965 | 108 | 12.8 | 200 | 0.877 | 581 | -955 | 1.56 | 3 | 1446.3 | 1053.4 | 833.1 | 604.6 | 448.4 | 240.5 | 113.7 | 40.4 | 2.9 |
| 36 | in G | 1 | 1413 | 33.5 | 24.6 | 0.591 | 850.5 | 608.2 | 410.6 | 296.9 | 219.4 | 118.4 | 74.3 | 47.8 | 0 | 1904 | 218 | 56.8 | 200 | 0.393 | 288 | -348 | 2.2 | 3.2 | 507.7 | 345.2 | 258.2 | 175.2 | 125.4 | 70.7 | 44 | 31 | 24.6 |
| 37 | Near | 1 | 1525 | 33.4 | 24.4 | 0.549 | 2286 | 1871.7 | 1462.9 | 1133.9 | 882.4 | 483.9 | 260.9 | 152.9 | 0 | 1704 | 84.2 | 13.2 | 200 | 1.27 | 520 | -1012 | 1.26 | 1.7 | 1262.8 | 1000.9 | 829 | 625.9 | 476.5 | 273.8 | 146.2 | 66.2 | 18.6 |
| 38 | -- | 1 | 1528 | 32.8 | 39.4 | 0.575 | 1137.6 | 914.4 | 655 | 511.7 | 403.8 | 237.2 | 140.7 | 101 | 88.5 | 2808 | 139 | 63.2 | 200 | 2.7 | 302 | -385 | 2.01 | 0.82 | 661.2 | 503.3 | 403.8 | 294.2 | 221.7 | 137.1 | 90.3 | 61.6 | 43.2 |
| 39 | -- | 1 | 1531 | 33.1 | 39.4 | 0.562 | 1577.6 | 1256.7 | 892.7 | 659.1 | 506.4 | 286.1 | 158.9 | 99.9 | 0 | 1740 | 110 | 32.6 | 200 | 1.35 | 439 | -625 | 2.08 | 2 | 899 | 671.3 | 532 | 381 | 280 | 156.9 | 86.8 | 45.8 | 22.6 |
| 40 | -- | 1 | 1536 | 32.5 | 39.4 | 0.571 | 1592.2 | 1136.4 | 585.9 | 352.6 | 268.7 | 174.7 | 0 | 0 | 0 | 964 | 82.2 | 76.5 | 200 | 0.594 | 660 | -455 | 4.21 | 6.1 | 921.5 | 579.4 | 393.8 | 223.8 | 135.5 | 62 | 36.4 | 26.1 | 21.6 |

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### 3.8.1 Options

Several user options are available as discussed below:

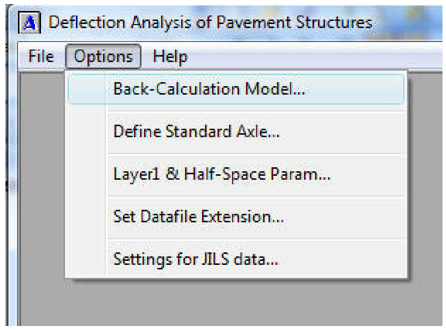


**Figure 3-8: Options**

**Back-Calculation Model:** DAPS supports three types of Back Calculations models (1) Rigid H-S and Sg Thickness (2) Known-Half Space (3) A,B,Subgrade . Based on the road conditions in the state of Karnataka it is recommended to use the *Rigid half space and Sg Thickness model* for the analysis of the FWD data.

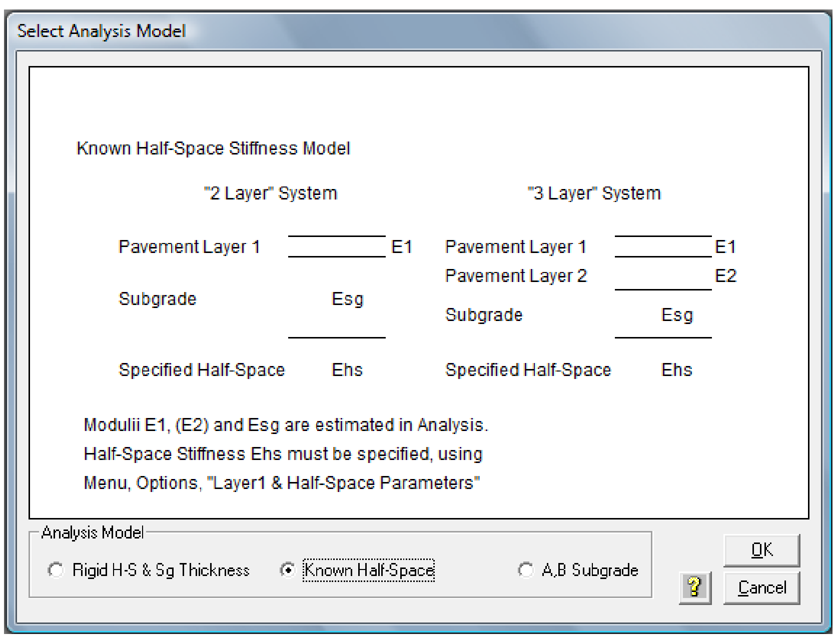


**Figure 3-9: Selecting Back-Calculation Model**

**Define Standard Axle:** The standard axle defined is used to determine these strains at critical locations. The standard Axle load define for Karnataka condition is shown in Figure 3-.

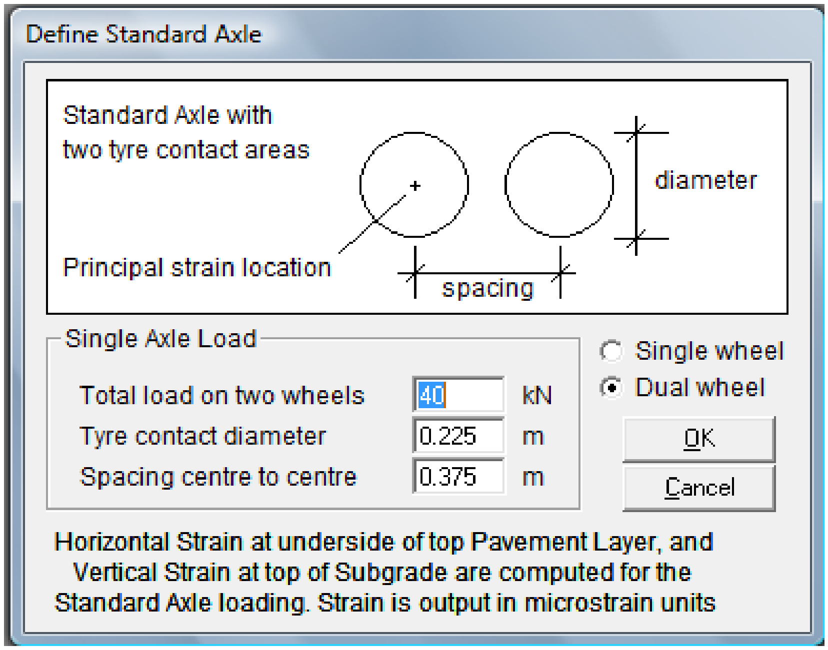


**Figure 3-10: Defining Standard Axle**

In the out-put file (*.bls) a calculation is provided of the strain in critical locations on the basis of the defined standard axle load.

**Layer 1 & Half Space Parameters:** The upper layer modulus can have a cut-off value selected. This is useful if analysing very thin pavement layers. In addition, it is possible to set a half-space stiffness (associated with the rock at depth).select the option **Specify a Limit**

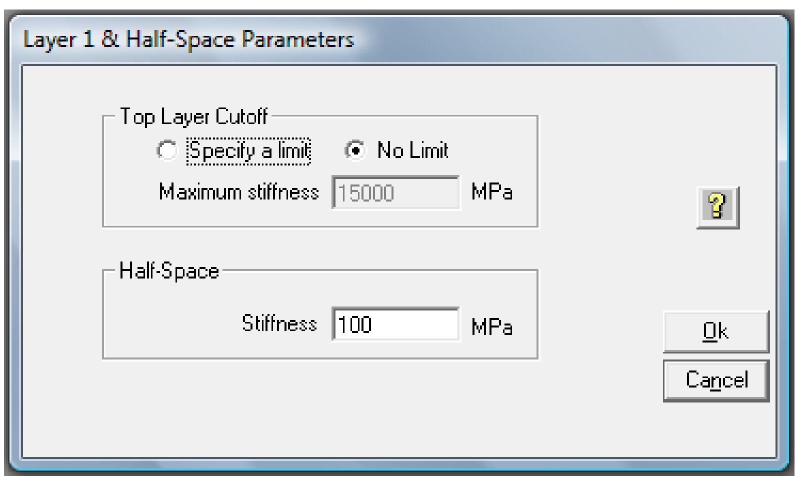


**Figure 3-8: Layer 1 & Half Space Parameters**

and provide maximum Stiffness limit to 15000 Mpa and Half space Stiffness to 200 Mpa

**Set Data file Extension:** The user can define the data file extension. This is useful in that non-needed data files can be filtered out by careful selection of data file extensions as csv

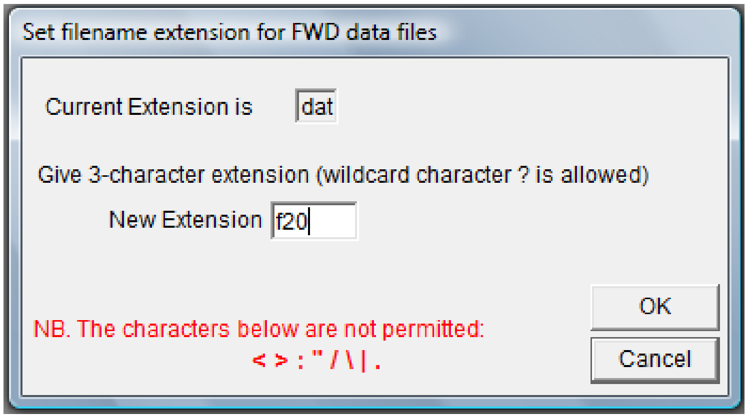


**Figure 3-9: Layer 1 & Half Space Parameters**

**Settings for JILS data:** In the JILS data file format various parameters (transducer spacing and load-plate diameter) are not defined. These must be defined in this dialog box to enable back-calculation.

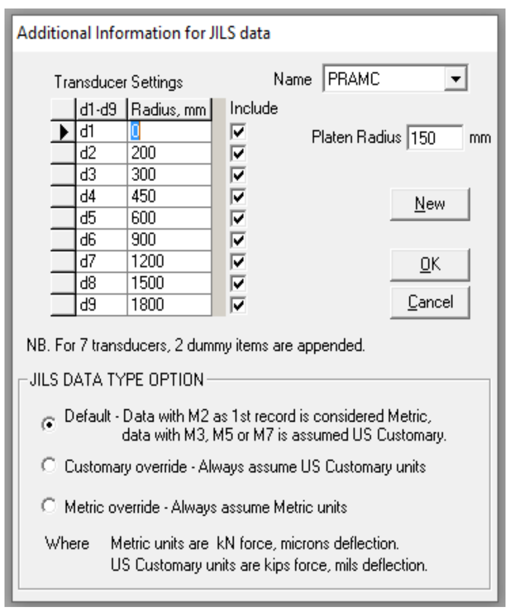


**Figure 3-10: Transducer spacing and load-plate diameter**

# 4. Data Processing -Ground Penetrating Radar (GPR)

## 4.1 General

After acquiring the radar data (scan) using GPR equipment, it has to be processed for determining the pavement layers thicknesses. For this purpose the GPR equipment is supplied along with a Georadar Data Elaboration High Density (GRED HD) software. This software is dedicated to the visualization of radar data acquired with the GPR system. In particular, it allows to process, elaborate and visualize the radar data in 2 and 3 dimensions, using the full potential of the 3D processing algorithms. The ensuing paragraphs elaborates the step by step procedure that covers an average GPR analysis from the elaboration of the raw data to the visualization of the results.

## 4.2 System requirements

For a proper use of the GRED HD Software the following are the minimum computer specification requirements

- Intel® Core™ i7 CPU M 620 @ 2.67GHz;
- 8 GB SDRAM;
- System type: 32-bit or 64-bit Operating System (with Administrator rights);
- 1 USB port for the installation of the HW key;
- Hard Disk SATA at least 7200 rpm and 250 GB (keep always 20 GB of free space);
- Graphic Adapter with 512 MB of dedicated memory;
- Ethernet 10/100 Base-T adaptor;
- 17 VGA Msync MPR » APM minimum Colour Monitor.

## 4.3 Software Module Sketch

GRED HD software is composed by the following 4 modules:

- BASIC,
- 3D,
- CAD,
- BRIDGE.

The ***BASIC*** module includes:

- Geographic Navigator,
- Import GeoTiff images,
- B-Scan data analyser
  - Processing and macro,
  - Generic target (single plot),

- Layers/cores in a 2D mode,
- Export layer to Excel,
- Export data to ASCII,
- Saving images,

Under PRAMC for the identification of the pavement layers the GRED HD **basic** module is used.

## 4.4 File menu

The *File* menu located in the software home screen consists of the commands *Open Project, Merge Project, Open File, Load Settings, Save Settings, Import, and Export.*

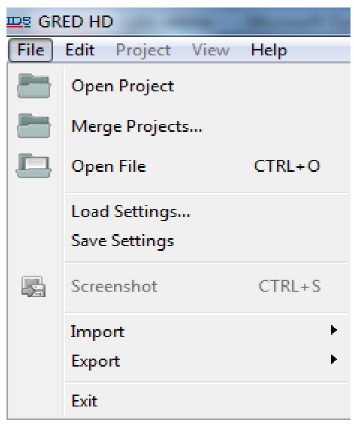


**Figure 4-1: File Menu- GRED HD software**

Usages of these sub-menus are given below

### *4.4.1 Open Project*

*Open Project* command is equivalent to the *Open project* button  and it opens the *Project selection* window from where the project folder containing the raw data can be selected (Figure 4-2).

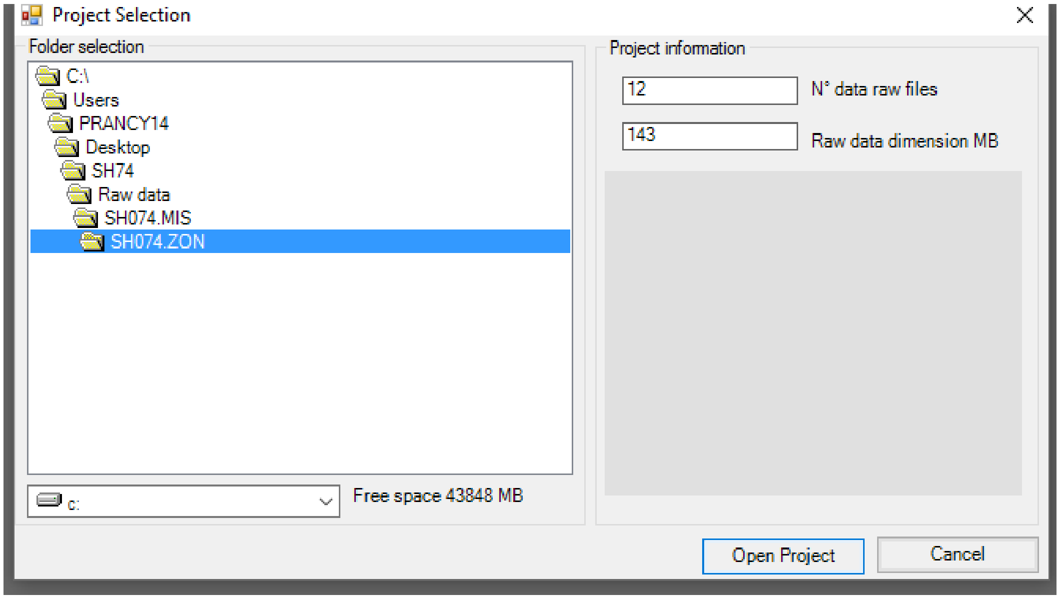


**Figure 4-2: Project Selection window**

Select the file for the identification of the layers, for Example SH074.ZON (Figure 4-2) and click on **Open Project.** As shown in the Figure 4-3 select the load mode as load default selection and click on **OK.**

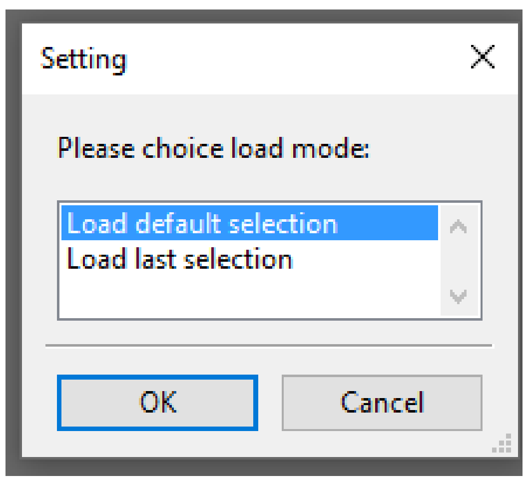


**Figure 4-3: Load Mode Selection window**

### *4.4.2 Data loading and positioning*

The first time when raw data is loaded, GRED HD software automatically starts the Geographical reference module (Figure 4-4). With this utility the software can properly calculate the relative position of each scan of GPR, using the information found in the files associated with the GPS positioning system used.

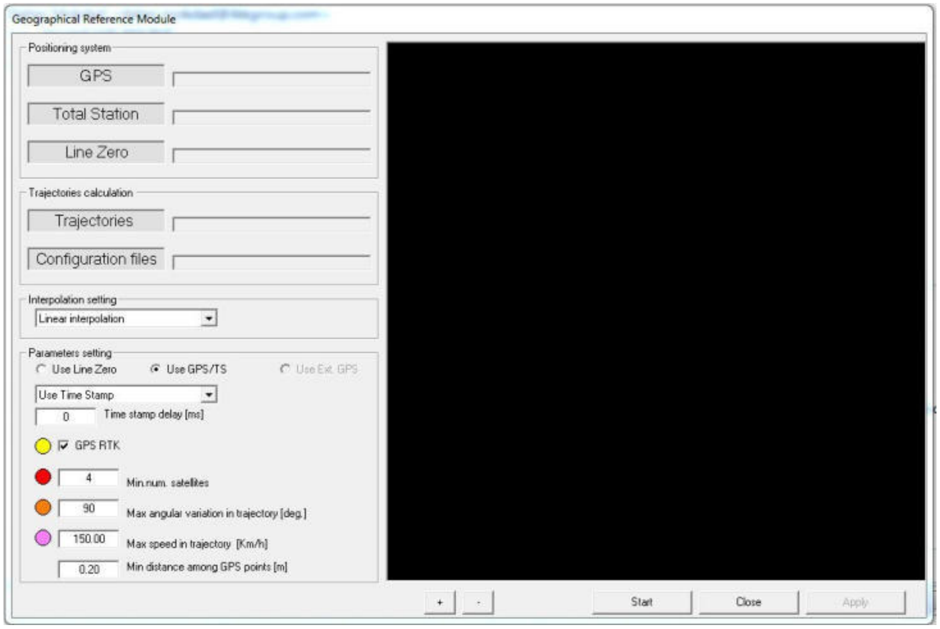


**Figure 4-4: Geographical reference module**

The position data is associated with the radar data with the following approaches:

**Timestamp**: The position data is associated with the radar data in accordance with a temporal proximity criterion. The GPR timestamp can be UTC in which case the association is completely reliable; or the timestamp of GPR is the local clock of the DAD, in which case it proceeds making an association between the two time scales associating the first radar track on the first position data received. In the latter case there may be problems due to the lag in the registration of strings.

**Marker GPS**: the position data is associated to the radar track that shows a mark created by the acquisition software. Bond of correspondence between the number of strings and the number of recorded radar tracks marked.

**Trajectories Extrapolation**: if there are gaps between the encoder wheel measurement and GPS measurement, then trajectories extrapolation technique can be useful. Note that, if the final points of the GPS are not displayed, the software will draw a straight line (in this case, this function should be used only if the final path is effectively straight).

**Linear interpolation**: it calculates how the points join up on straight paths

**Spline interpolation**: is the most "smoothing" (continuity of the first and second derivative in the junction points) and follows better the curves but sometimes it can be oscillating in due to abrupt transitions in joining the points.

**Mixed interpolation**: it follows "faster" the points and does not generate oscillations, it guarantees the continuity of the first derivative alone and it is less smooth. Essentially, it applies spline interpolation to the intermediate points and linear interpolation at the beginning and end of the trajectory.

If there are a number of radar tracks acquired prior to the first measurement point position and after the last point, the software module performs an extrapolation placing these radar tracks on the path tangent to the at the first / last point measure.

When the process is over (clicking START + APPLY in Figure 4-4) the software will plot the referenced scans in the main interface as shown Figure 4-5.

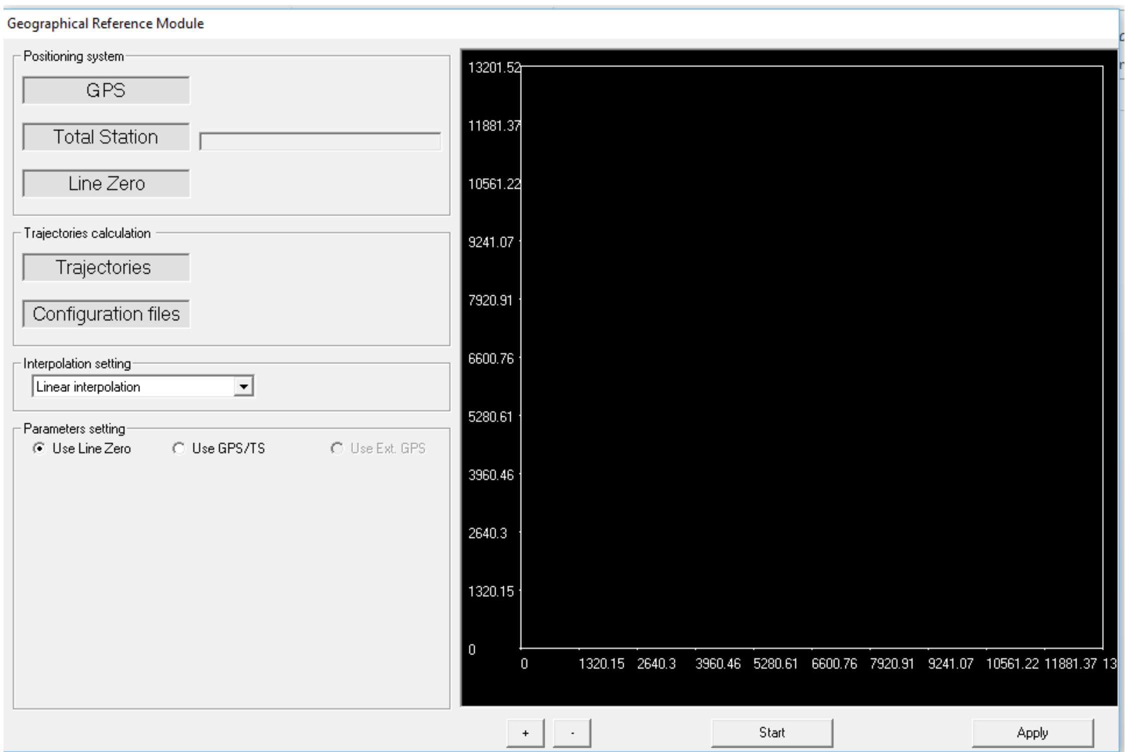


**Figure 4-5: Processing of Geographical Reference Module without GPS coordinates**

- The Navigation window will be displayed as shown in Figure 4-6

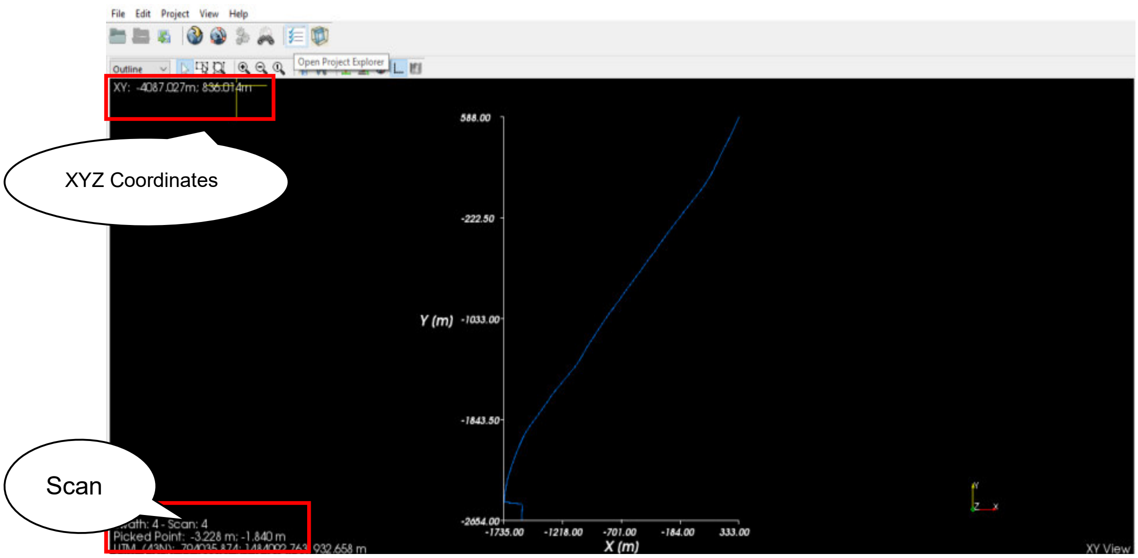


**Figure 4-6: Navigation window with reference scans**

- This menu gives all the options related to the visualization of the maps. The Section's commands are:
  - Project Explorer (  ): it opens the Project Explorer window (Figure 4-7) (shortcut ALT + F4).
  - In order to visualize swaths, in Project Explorer( Figure 4-7 )selects scans, Antenna Array (when present), Data extension (.DT, .D00, .D01, .D##)
  - A single scan can be selected by clicking one time with the left mouse button on the swath (L scans) and then select View. In order to visualize only selected radar maps click on View button.

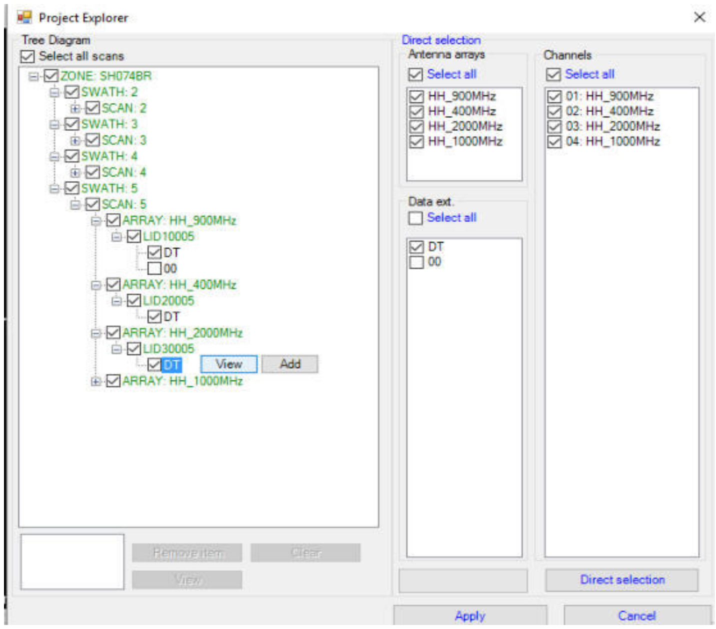


**Figure 4-7: Project Explorer Tree**

- The scanned layers of the road from the scan selected will be displayed as shown in Figure 4-8.

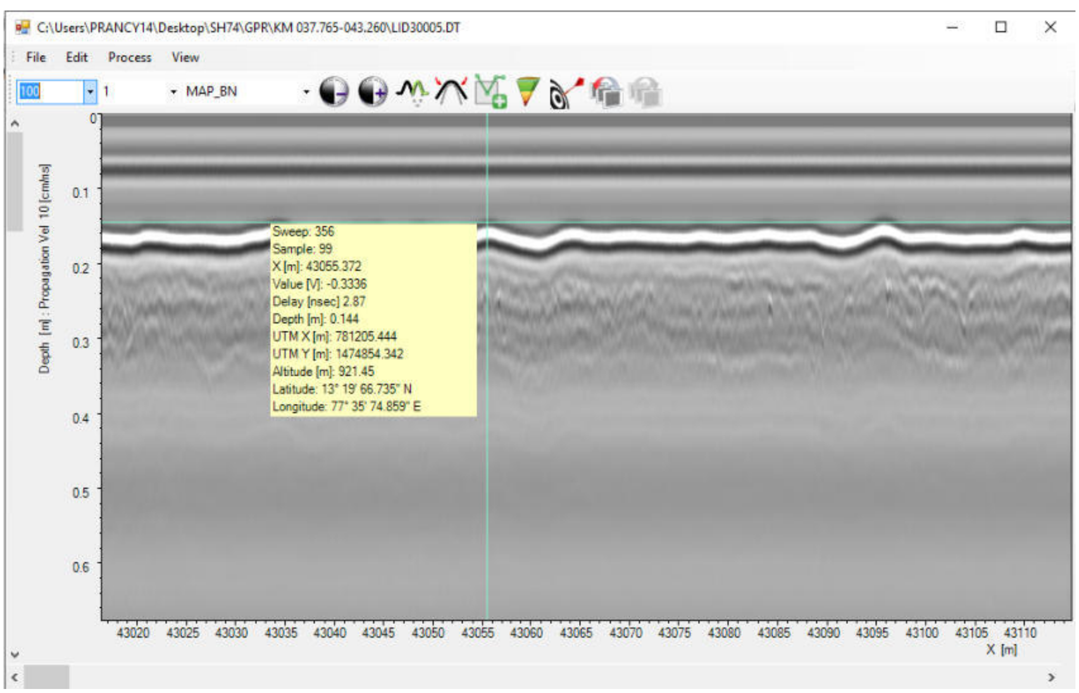


**Figure 4-8: Window Showing the Scanned Layers**

Following steps are to be applied for optimizing the viewer window for the identification of the pavement layers

- The layer that is being observed in the Figure 4-8 the peak point on the entire scan is to be identified by visual observation.
- By right clicking on the visualized peak the Delay (n sec) is to be recorded for the future reference.
- Open the process menu and Select the “Settings/ (Ctrl+Y)” as shown in Figure 4-9 and Figure 4-10.

### *4.4.3 Settings- Processing the Layers*

The following is the list of the Settings to be adopted for processing the Layer Scan details collected from the field. Refer process as shown in the Figure 4-9

**A. 2000Mhz Antenna:**

- Move Start Time: remove the Automatic Selection and input the “n sec”(Delay in Start of Scan) i.e., n sec value is obtained by right clicking on the Peak Point Identified on the Surface Layer as shown in Figure 4-8
- Time Domain Band Pass Filter: 1000 (Low Frequency), 3000 (High Frequency) as shown in Figure 4-10
- Now Click on **Apply,** and followed by functions F1, F3, F4, F2, to apply all the necessary settings that are to be modified

**B. 1000Mhz Antenna:**

- Move Start Time: remove the Automatic Selection and input the “n sec”(Delay in Start of Scan) i.e., n sec value is obtained by right clicking on the Peak Point Identified on the Surface Layer as shown in Figure 4-8
- Time Domain Band Pass Filter: 500 (Low Frequency), 2000 (High Frequency) as shown in Figure 4-10
- Now Click on Apply, and followed by functions F1, F3, F4, F2, to apply all the necessary settings that are to be modified

**C. 900Mhz Antenna:**

- Move Start Time: Select the Automatic Mode
- Time Domain Band Pass Filter: 300 (Low Frequency), 1500 (High Frequency) as shown in Figure 4-10
- Gain: 200
- Now Click on **Apply**, and followed by functions F1, F3, F4, F2, to apply all the necessary settings that are to be modified

**D. 400Mhz Antenna:**

- Move Start Time: Select the Automatic Mode
- Time Domain Band Pass Filter: 100 (Low Frequency), 1000 (High Frequency) as shown in Figure 4-10

- Gain: 200
- Now Click on **Apply,** and followed by functions F1, F3, F4, F2 to apply all the necessary settings that are to be modified

- Applying the Modified Settings based on the antenna Selected, the processed Data will appear as shown in Figure 4-11.

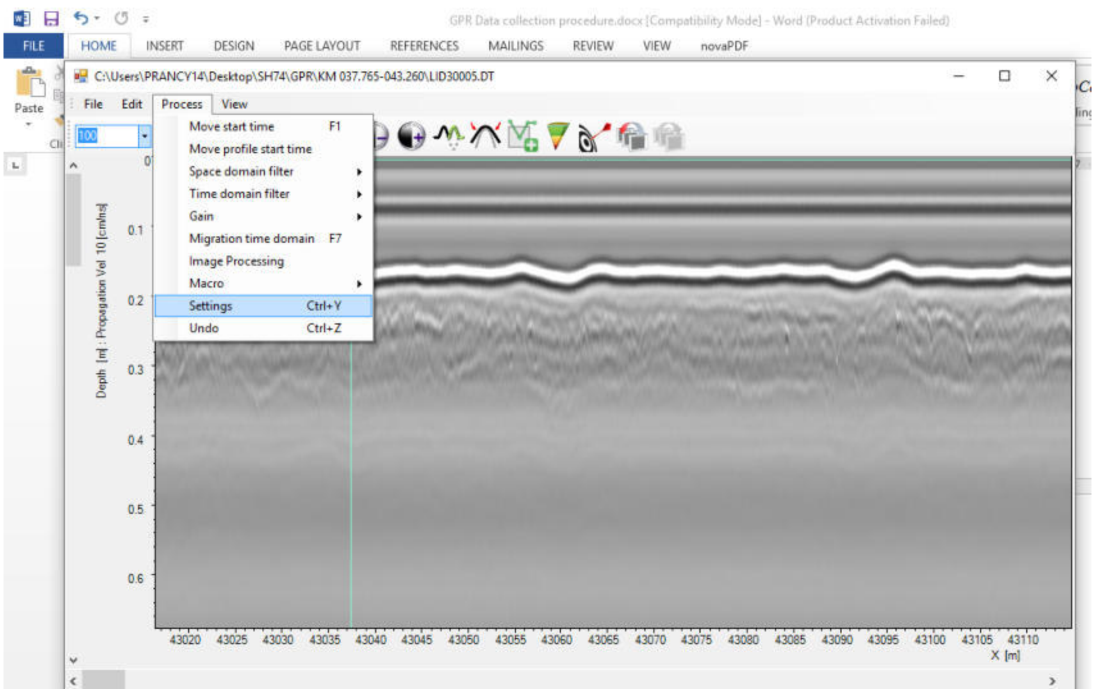


**Figure 4-9: Process Setting Menu**

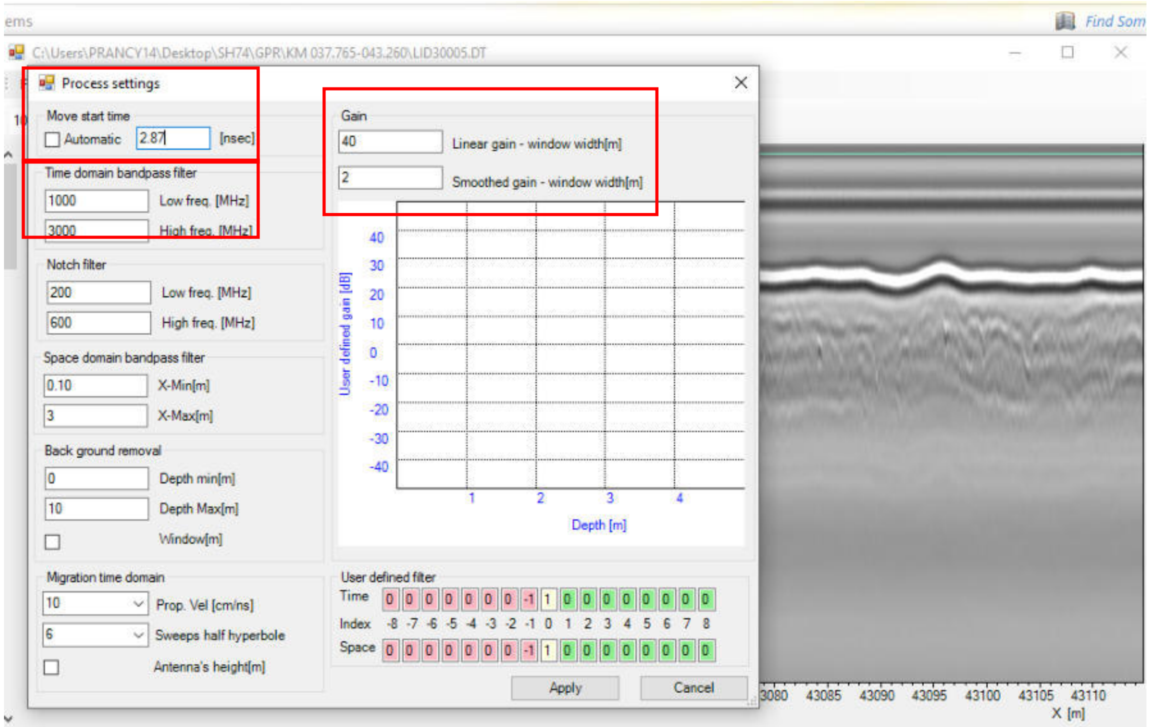


Figure 4-10: Process Setting Window

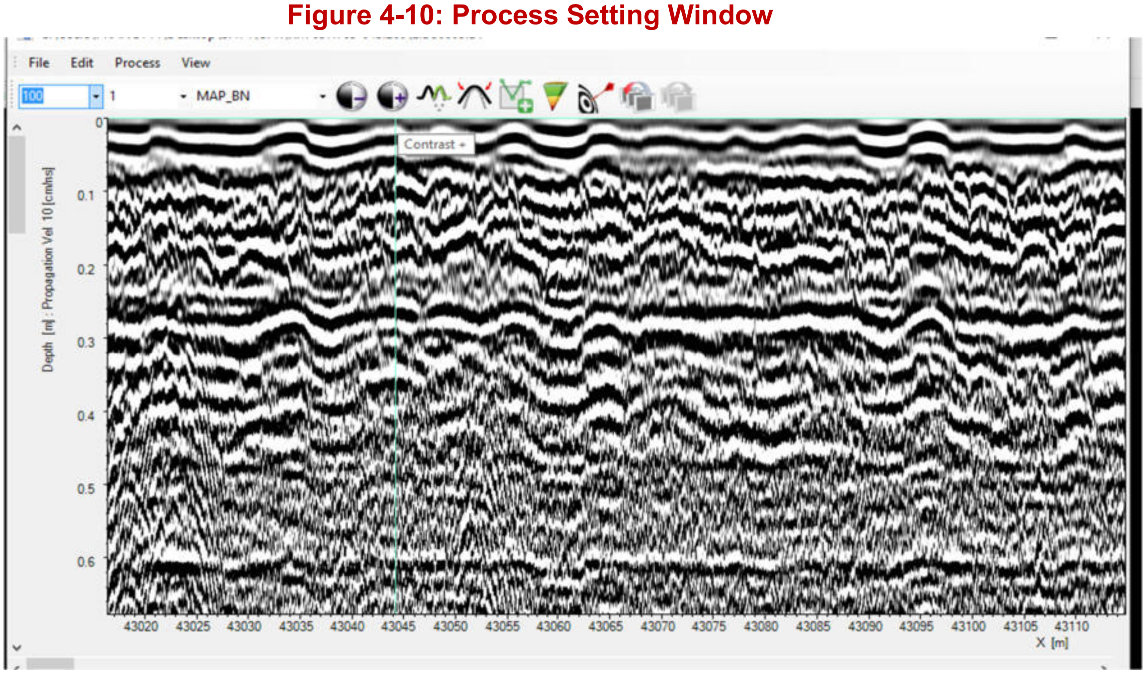


Figure 4-11: Processed Layers Window after the Application of the Required Setting

- Layers to be plotted as overlay on the identified GPR radar data, using the "New Layer" Tool as shown in Figure 4-12.

- Layer can be plotted in both *Manual* and *automatic* modes, in which layer start point is to be identified manually and further it can be shifted to automatic mode or can be continued with manual plotting of the pavement layer;
- After completion of plotting the layer save the layer by right click.

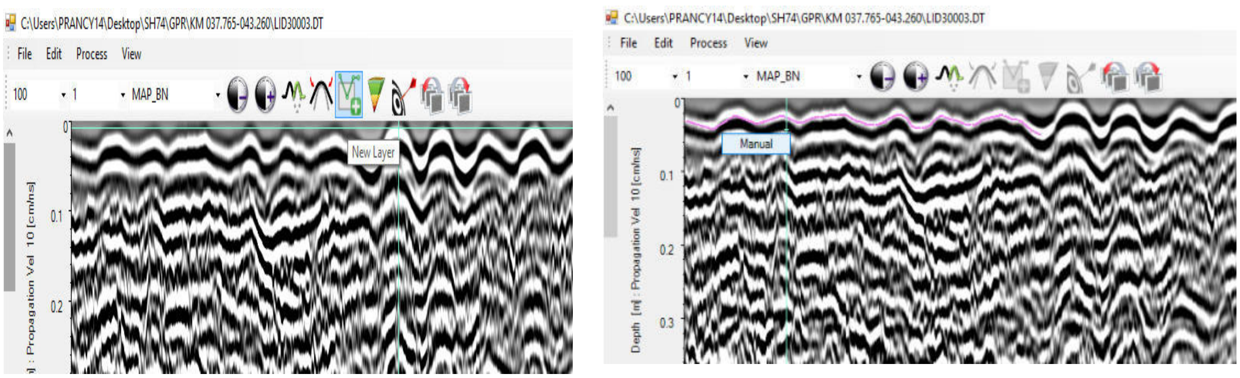


**Figure 4-12: Plotting the Pavement Layers**

- Plot the required layers i.e., Top Surface of the Asphaltic Layer, Top Surface of the Granular Sub base, Top Surface of the Sub Grade Layer.
- The plotted layers require calibration at intervals of 5Kms

### *4.4.4 Calibration of the Plotted Layers*

- Use core details at the chainage where the test Pit Data is collected by selecting the Option "**Insert Core**" input the Layer depth of each layer from top (refer Figure 4-13).
    - For Example: from the Collected Test Pit Data thickness of the Asphalt Layer is 100mm, Granular Sub base is 250mm
    - For Layer 1 starts from the top of the scan enter the Dummy Value as 0.05m
    - For Layer 2 of Asphalt Layer Thickness will be 0.05+0.10 = 0.15 in meters
    - For Layer 3 of Granular Sub base thick ness will be 0.05+0.10+0.25 = 0.4 in Meters
- Now click on *Apply* to apply the Calibration and the layer Legend of the calibrated layers can be seen using the *"View"* option followed by *"Layer Legend"* in the menu bar as shown in Figure 4-14.

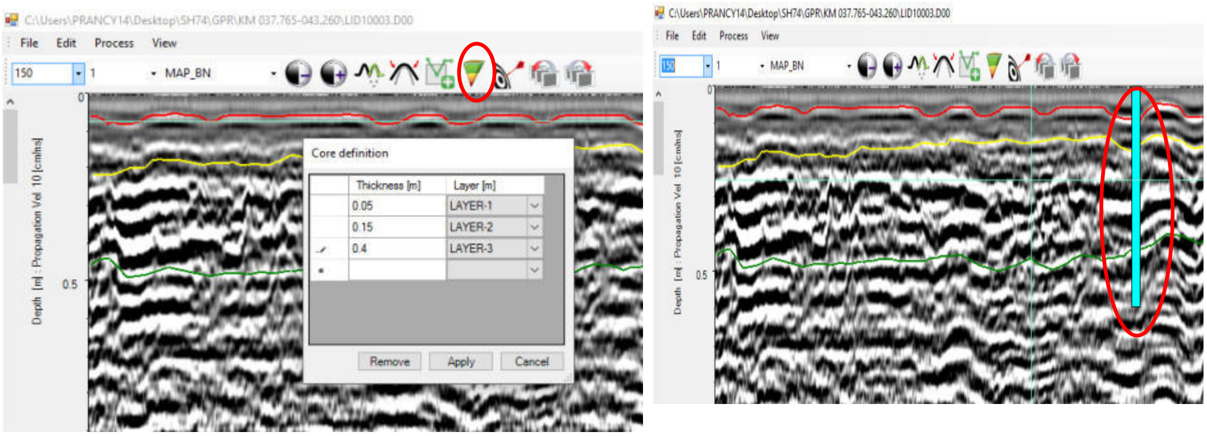


**Figure 4-13: Inserting the core Details**

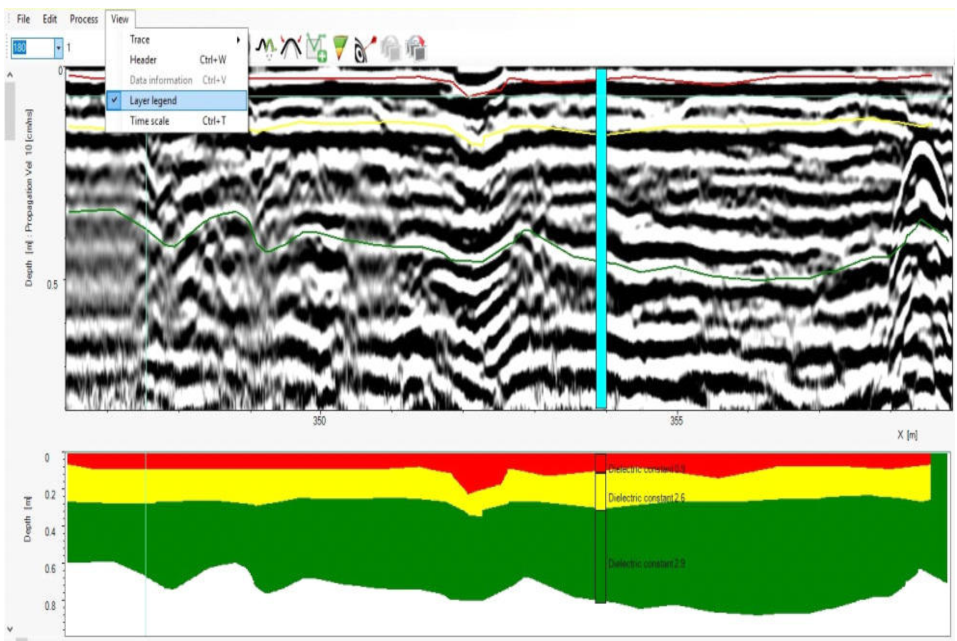


**Figure 4-14: Layer Legend**

### *4.4.5 Results Generation*

1. All the above mentioned Process of Plotting Layers and Calibration is performed in the Data extension (.DT) and now it will be further saved as data extension .D00 by using "**menu bar** ⇨ **File** ⇨ **Save**" options, and similar exercises can be performed any number of times and can be saved as data extension (.D01, .D02, .D03…..) as shown in Figure 4-15.

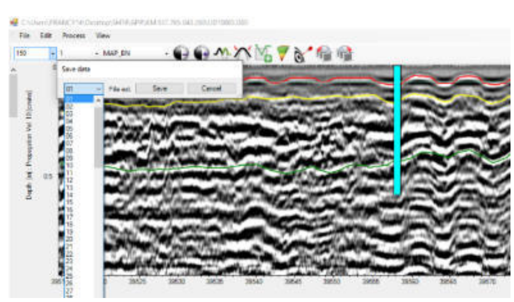

**Figure 4-15: Saving the Plotted Layers**

2. The plotted layers can be exported to the MS Excel Format (.csv) and prescribed interval can be selected as shown in Figure 4-16.
3. The exported layers details obtained with the selected interval will show the depth of each layer from the top surface of the road Scan as shown in Figure 4-17.
4. The actual asphalt Layer Thickness is available by subtracting the Layer 1 from Layer 2 of the exported results spread sheet and similarly the Granular Sub base thickness is obtained by subtracting the Layer 2 from Layer 3 as shown in Figure 4-18.

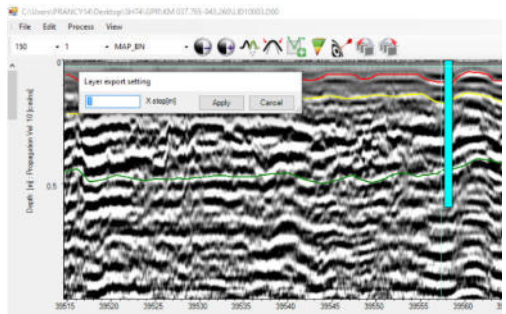

**Figure 4-16: Exporting the Layers to Ms Excel**

| | A<br>X [m] | C<br>Latitude | D<br>Longitude | E<br>LAYER-1: Depth [m] | F<br>LAYER-2: Depth [m] | G<br>LAYER-3: Depth [m] |
|---|---|---|---|---|---|---|
| 2 | | | | | | |
| 3 | 166240 | 13° 31' 68.989" N | 77° 14' 57.611" E | 0.082 | 0.153 | 0.418 |
| 4 | 166340 | 13° 31' 74.098" N | 77° 14' 59.396" E | 0.082 | 0.156 | 0.441 |
| 5 | 166440 | 13° 31' 79.420" N | 77° 14' 60.357" E | 0.055 | 0.134 | 0.461 |
| 6 | 166540 | 13° 31' 84.736" N | 77° 14' 61.318" E | 0.059 | 0.137 | 0.473 |
| 7 | 166640 | 13° 31' 90.103" N | 77° 14' 62.234" E | 0.061 | 0.152 | 0.457 |
| 8 | 166740 | 13° 31' 95.407" N | 77° 14' 63.012" E | 0.082 | 0.183 | 0.462 |
| 9 | 166840 | 13° 32' 0.769" N | 77° 14' 63.653" E | 0.059 | 0.145 | 0.454 |
| 10 | 166940 | 13° 32' 6.130" N | 77° 14' 64.202" E | 0.069 | 0.191 | 0.473 |
| 11 | 167040 | 13° 32' 11.503" N | 77° 14' 64.797" E | 0.077 | 0.185 | 0.465 |
| 12 | 167140 | 13° 32' 16.928" N | 77° 14' 65.255" E | 0.059 | 0.152 | 0.473 |
| 13 | 167240 | 13° 32' 22.249" N | 77° 14' 65.850" E | 0.086 | 0.186 | 0.487 |
| 14 | 167340 | 13° 32' 27.640" N | 77° 14' 66.262" E | 0.057 | 0.147 | 0.398 |
| 15 | 167440 | 13° 32' 33" N | 77° 14' 65.667" E | 0.078 | 0.156 | 0.453 |
| 16 | 167540 | 13° 32' 38.357" N | 77° 14' 65.026" E | 0.059 | 0.136 | 0.484 |
| 17 | 167640 | 13° 32' 43.730" N | 77° 14' 64.385" E | 0.082 | 0.168 | 0.477 |
| 18 | 167740 | 13° 32' 49.040" N | 77° 14' 63.607" E | 0.078 | 0.148 | 0.480 |
| 19 | 167840 | 13° 32' 54.379" N | 77° 14' 62.600" E | 0.070 | 0.136 | 0.448 |
| 20 | 167916 | 13° 32' 58.356" N | 77° 14' 61.639" E | | | |
| 21 | | | | | | |

**Figure 4-17: Exported Layers Thickness**

| | A<br>X [m] | C<br>Latitude | D<br>Longitude | E<br>LAYER-1: Depth [m] | F<br>LAYER-2: Depth [m] | G<br>LAYER-3: Depth [m] | H<br>Thickness (mm) | I |
|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | | Bituminous | Granular |
| 3 | 166240 | 13° 31' 68.989" N | 77° 14' 57.611" E | 0.082 | 0.153 | 0.418 | 71 | 265 |
| 4 | 166340 | 13° 31' 74.098" N | 77° 14' 59.396" E | 0.082 | 0.156 | 0.441 | 74 | 285 |
| 5 | 166440 | 13° 31' 79.420" N | 77° 14' 60.357" E | 0.055 | 0.134 | 0.461 | 79 | 327 |
| 6 | 166540 | 13° 31' 84.736" N | 77° 14' 61.318" E | 0.059 | 0.137 | 0.473 | 78 | 336 |
| 7 | 166640 | 13° 31' 90.103" N | 77° 14' 62.234" E | 0.061 | 0.152 | 0.457 | 91 | 305 |
| 8 | 166740 | 13° 31' 95.407" N | 77° 14' 63.012" E | 0.082 | 0.183 | 0.462 | 101 | 279 |
| 9 | 166840 | 13° 32' 0.769" N | 77° 14' 63.653" E | 0.059 | 0.145 | 0.454 | 86 | 309 |
| 10 | 166940 | 13° 32' 6.130" N | 77° 14' 64.202" E | 0.069 | 0.191 | 0.473 | 122 | 282 |
| 11 | 167040 | 13° 32' 11.503" N | 77° 14' 64.797" E | 0.077 | 0.185 | 0.465 | 108 | 280 |
| 12 | 167140 | 13° 32' 16.928" N | 77° 14' 65.255" E | 0.059 | 0.152 | 0.473 | 93 | 321 |
| 13 | 167240 | 13° 32' 22.249" N | 77° 14' 65.850" E | 0.086 | 0.186 | 0.487 | 100 | 301 |
| 14 | 167340 | 13° 32' 27.640" N | 77° 14' 66.262" E | 0.057 | 0.147 | 0.398 | 90 | 251 |
| 15 | 167440 | 13° 32' 33" N | 77° 14' 65.667" E | 0.078 | 0.156 | 0.453 | 78 | 297 |
| 16 | 167540 | 13° 32' 38.357" N | 77° 14' 65.026" E | 0.059 | 0.136 | 0.484 | 77 | 348 |
| 17 | 167640 | 13° 32' 43.730" N | 77° 14' 64.385" E | 0.082 | 0.168 | 0.477 | 86 | 309 |
| 18 | 167740 | 13° 32' 49.040" N | 77° 14' 63.607" E | 0.078 | 0.148 | 0.480 | 70 | 332 |
| 19 | 167840 | 13° 32' 54.379" N | 77° 14' 62.600" E | 0.070 | 0.136 | 0.448 | 66 | 312 |
| 20 | 167916 | 13° 32' 58.356" N | 77° 14' 61.639" E | | | | | |

**Figure 4-18: Corrected Layers Thickness**

## 4.5 Application of GPR and FWD Results

- The results are used as input for the Analysis of Various Modules in Karnataka Road Asset Management System (KRAMS)
- The surface and base thickness details from GPR results are used for the Surface and base thickness details of KRAMS format whereas remaining data required is obtained from the FWD generated results and the sample KRAMS Format is shown in Table 4-1.

**Table 4-1: KRAMS Format- FWD and GPR Results**

| Road_ID | Road_ Name | From | To | Survey_Da te | Link_ID | Direction | Lane | Surf_Thick (mm) | Base_Thick (mm) | Surf_ Type | Base_ Type | SubBase _Thick(m m) | SubBase _Type | CBR(%) | SNP | Disp0_0 | Disp1_200 | Disp2_300 | Disp3_450 | Disp4_600 | Disp5_900 | Disp6_1 200 | Disp7_ 1500 | Disp8_ 1800 | Air_ Temp | Pav_ Temp | Press ure | Data_ Sourc e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH2 | Highwa | 0 | 500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 500 | 1000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 1000 | 1500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 1500 | 2000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 2000 | 2500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 2500 | 3000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 3000 | 3500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 3500 | 4000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | Highwa | 4000 | 4500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | muru via | 4500 | 5000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | muru via | 5000 | 5500 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |
| SH2 | muru via | 5500 | 6000 | 19-Sep-16 | SRS3 | I | L1 | 60 | 250 | AC | GB | 500 | SG | 6 | 3.5635 | 0.8430 | 0.7430 | 0.5167 | 0.3575 | 0.2622 | 0.1292 | 0.0563 | 0.0381 | 0.0254 | 28.97 | 24.95 | 700 | Pave |

**GPR Results**

**FWD Results**

- Deflection results collected should be in millimetres and to be normalised for 700Kpa pressure.
- SNC=3.2*$d_0$^(-0.63)

  Where,

  SNC = Structural Number Corrected

  $d_0$ = Deflection of the first geophone value in millimetre.

# ANNEXURE

## Data Compilation Formats with sample data - ROMDAS

## Survey Header

| SURVEY_ID | SURVEY_FILE | SURVEY DESCRIPTION | SURVEY DATE | VEHICLE | OPERATOR | CHAIN_ START | CHAIN_ END | DIRECTION | LANE | DEVICES | VERSION | LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

## GPS

| Road_ID | Link_ID | Chainage | Speed | Latitude | Longitude | altitude | Survey_Date | Direction | CRS(Coor.Ref.System) |
|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 5 | 13.14082 | 74.77219 | 23.600 | 20-Apr-16 | I | UTM WGS1984 ZONE43N |
| SH1 | UDP203 | 5 | 9 | 13.14080 | 74.77223 | 23.600 | 20-Apr-16 | I | UTM WGS1984 ZONE43N |
| SH1 | UDP203 | 10 | 12 | 13.14079 | 74.77227 | 23.600 | 20-Apr-16 | I | UTM WGS1984 ZONE43N |

## IRI

| Road_ID | Link_ID | From | To | Direction | Lane | LWP_IRI | RWP_IRI | Lane_IRI | Speed | SurveyDate |
|---|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 100 | I | 1 | 1.12 | 2.02 | 1.57 | 19 | 20-Apr-16 |
| SH1 | UDP203 | 100 | 200 | I | 1 | 2.12 | 1.88 | 2.00 | 41 | 20-Apr-16 |
| SH1 | UDP203 | 200 | 300 | I | 1 | 2.72 | 1.56 | 2.14 | 42 | 20-Apr-16 |

## Road Type

| Road_ID | Link_ID | From | To | Direction | Road_Type | SurveyDate |
|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 10245 | I | Double Lane | 20-Apr-16 |
| SH1 | KRK40 | 10245 | 15258 | I | Double Lane | 20-Apr-16 |
| SH1 | KRK40 | 15258 | 15556 | I | Multi Lane | 20-Apr-16 |

## Pavement Width

| Road_ID | Link_ID | From | To | Direction | Pave_Width | Road_Width | No of Lanes | SurveyDate |
|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 10245 | I | 7 | 11 | 2 | 20-Apr-16 |
| SH1 | KRK40 | 10245 | 15258 | I | 7 | 11 | 2 | 20-Apr-16 |
| SH1 | KRK40 | 15258 | 15556 | I | 10 | 14 | 2.2 | 20-Apr-16 |

## Surface Type

| Road_ID | Link_ID | From | To | Surf_Type | SurveyDate |
|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 10245 | Bituminous | 20-Apr-16 |
| SH1 | KRK40 | 10245 | 15262 | Bituminous | 20-Apr-16 |
| SH1 | KRK40 | 15262 | 15564 | Bituminous | 20-Apr-16 |

## Shoulder Type

| Road_ID | Link_ID | From | To | Direction | Shd_Type | SurveyDate |
|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 769 | 1 | Paved | 20-Apr-16 |
| SH1 | UDP203 | 769 | 3493 | 1 | Paved | 20-Apr-16 |
| SH1 | UDP203 | 3493 | 3743 | 1 | Paved | 20-Apr-16 |

## Shoulder Width

| Road_ID | Link_ID | From | To | Direction | Shd_Width | SurveyDate |
|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 87 | I | 1.5 | 20-Apr-16 |
| SH1 | UDP203 | 87 | 752 | I | 2 | 20-Apr-16 |
| SH1 | UDP203 | 752 | 3419 | I | 1.5 | 20-Apr-16 |

## Shoulder Elevation

| Road_ID | Link_ID | From | To | Direction | Shd_elevation | SurveyDate |
|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 1672 | I | Levelled Shoulder | 20-Apr-16 |
| SH1 | UDP203 | 1672 | 10245 | I | Shoulder Drop | 20-Apr-16 |
| SH1 | KRK40 | 10245 | 28185 | I | Shoulder Drop | 20-Apr-16 |

## Drain Type

| Road_ID | Link_ID | From | To | Direction | Drain_Type | SurveyDate |
|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 506 | I | Lined drain | 20-Apr-16 |
| SH1 | UDP203 | 506 | 3276 | I | Unlined drain | 20-Apr-16 |
| SH1 | UDP203 | 3276 | 3620 | I | Lined drain | 20-Apr-16 |

## Rutting

| Road_ID | Link_ID | From | To | Direction | Lane | LWP_Rut | RWP_Rut | Lane_Rut | Speed | SurveyDate |
|---|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 100 | I | 1 | 17.3 | 16.9 | 16.9 | 19 | 20-Apr-16 |
| SH1 | UDP203 | 100 | 200 | I | 1 | 3.7 | 3.1 | 3.1 | 41 | 20-Apr-16 |
| SH1 | UDP203 | 200 | 300 | I | 1 | 3.4 | 3.1 | 3.1 | 42 | 20-Apr-16 |

## Texture

| Road_ID | Link_ID | From | To | LWP_MPD | RWP_MPD | Lane_MPD | Survey Date |
|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 100 | 1.12 | 0.74 | 0.93 | 20-Apr-16 |
| SH1 | UDP203 | 100 | 200 | 0.85 | 0.57 | 0.71 | 20-Apr-16 |
| SH1 | UDP203 | 200 | 300 | 0.85 | 0.64 | 0.75 | 20-Apr-16 |

## ESIS: Road Side Amenities

| Road Id | Link_ID | Chainage | Land Use Pattern | Survey Date | Road Name |
|---|---|---|---|---|---|
| SH1 | UDP203 | 3268 | 5 | 20-Apr-16 | Highway connecting Padubedri with Chickalaguda Karkala:Agumbe:Thirthahalli:Anandapura:Hangal:Thadasa:Kalghatagi:Dharwad:Uppinabetegeri:Belawadi:Bailahongala:Vannuru:Hoskoti:Ankalagi:Basapura:Hidkal Dam and Hosur |
| SH1 | UDP203 | 4388 | 5 | 20-Apr-16 | Highway connecting Padubedri with Chickalaguda Karkala:Agumbe:Thirthahalli:Anandapura:Hangal:Thadasa:Kalghatagi:Dharwad:Uppinabetegeri:Belawadi:Bailahongala:Vannuru:Hoskoti:Ankalagi:Basapura:Hidkal Dam and Hosur |
| SH1 | UDP203 | 5441 | 5 | 20-Apr-16 | Highway connecting Padubedri with Chickalaguda Karkala:Agumbe:Thirthahalli:Anandapura:Hangal:Thadasa:Kalghatagi:Dharwad:Uppinabetegeri:Belawadi:Bailahongala:Vannuru:Hoskoti:Ankalagi:Basapura:Hidkal Dam and Hosur |

## RMMS: Road Furniture

| Road_ID | Link_ID | From | To | Direction | RdFur_Type | RdFur_Cond | Repainting | SurveyDate |
|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 64 | 64 | I | 2 | Poor | Y | 20-Apr-16 |
| SH1 | UDP203 | 265 | 265 | I | 2 | Poor | N | 20-Apr-16 |
| SH1 | UDP203 | 638 | 638 | I | 2 | Poor | Y | 20-Apr-16 |

## RMMS: Tree

| Road ID | Link_ID | From | To | Direction | Tree_Type | Tree_ID | Obstruction_Cond (Major/Minor) | Survey Date |
|---|---|---|---|---|---|---|---|---|
| SH1 | TRT3 | 80099 | 80099 | I | 3 | | Poor | 20-Apr-16 |
| SH1 | TRT3 | 114804 | 114804 | I | 3 | | Poor | 02-May-16 |
| SH1 | TRT3 | 114843 | 114843 | I | 3 | | Poor | 02-May-16 |

## RMMS: Road Marking

| Road ID | Link_ ID | Fro m | To | Direct ion | Edge_Marking_Re qd (Y/N) | CL_Marking_Re qd (Y/N) | Survey Date | Road Marking Type |
|---|---|---|---|---|---|---|---|---|
| SH1 | UDP2 03 | 0 | 102 45 | I | | Poor | 20-Apr-16 | 1 |
| SH1 | UDP 203 | 0 | 102 45 | I | Poor | | 20-Apr-16 | 3 |
| SH1 | KRK4 0 | 102 45 | 770 21 | I | | Poor | 20-Apr-16 | 1 |

## RMMS: Median

| Road ID | Link_I D | From | To | Directio n | Med_Typ e | Med_Widt h | Med_Con d | Survey Date |
|---|---|---|---|---|---|---|---|---|
| SH1 | KRK40 | 1527 8 | 1553 7 | I | 3 | 1 | poor | 20-Apr-16 |
| SH1 | KRK40 | 4516 4 | 4540 9 | I | 3 | 1 | poor | 20-Apr-16 |
| SH1 | KRK40 | 4547 7 | 4552 6 | I | 3 | 1 | poor | 20-Apr-16 |

## Visual Condition

| Road_ID | Link_ID | From | To | Direction | Lane | Bleeding | Cracking | Depression | Edge_Damage | Patching | Potholes | Ravelling | Shoulder_Condition | Shoving | Drainage_Condition | Survey Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 500 | I | 1 | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Good | Very Good | Good | 20-Apr-16 |
| SH1 | UDP203 | 500 | 1000 | I | 1 | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Good | Very Good | Good | 20-Apr-16 |
| SH1 | UDP203 | 1000 | 1500 | I | 1 | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Very Good | Good | Very Good | Bad | 20-Apr-16 |

## LRP

| Road_ID | Link_ID | LRP_ID | LRP_Name | Type | Description | Offset | Prev_LRP | LRP_Offset | Diagram | Photo | Latitude | Longitude | Altitude | StartDate | EndDate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | LRP_SH1_0 | NH 66 Jn padubidari | INT | NH 66 Jn padubidari | 0 | LRP_SH1_0 | 0 | NULL | NULL | 13.140824 | 74.772194 | 23.600 | 20-Apr-16 | 20-Apr-16 |
| SH1 | KRK40 | LRP_SH1_33789 | Kadu road Jn | INT | Kadu road Jn | 33789 | LRP_SH1_0 | 33789 | NULL | NULL | 13.232850 | 74.985044 | 81.400 | 20-Apr-16 | 20-Apr-16 |

## Vertical Geometry

| Road_ID | Link_Id | From | To | Direction | Geometry Type | Speed | Gradient(%) | Curvature(deg/km) | Camber(%) | RF(m/km) | Num_RF | Altitude | Super Elevation(%) | Cross_slope(%) | Survey_Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH1 | UDP203 | 0 | 100 | I | Plain | 10 | -1.10000 | | 2.5 | -1.10 | 1 | 23.600 | 2.5 | 5 | 20-Apr-16 |
| SH1 | UDP203 | 100 | 200 | I | Plain | 32 | 2.70000 | | 2.5 | 2.70 | 1 | 22.500 | 2.5 | 5 | 20-Apr-16 |