CHAPTER – 4
Engineering Surveys and Investigation

4.1 General

A sound engineering approach has been developed based on the requirement stipulated in Terms of Reference for conducting the required field surveys. Following data were collected from site and detailed study has been carried out to formulate a systematic approach towards the present assignment. Following primary field surveys and investigations have been carried out on the project road.

- **Inventory**
  - Road
  - Cross Drainage Structures

- **Condition Surveys**
  - Pavement condition survey
  - Cross Drainage Structure

- **Topographic Survey**
  - Longitudinal alignment
  - Cross sections at 50 m interval in plain area
  - Cross section of Cross Drainage channels / streams

- **Pavement Investigations**
  - Trial Pit Investigation
  - Sub-grade Investigation
  - Benkelman Beam Deflection Test
  - Axle Load Survey

- **Material Survey**
  - Soil from Borrow Area
  - Aggregate Sources
  - Sand Sources
  - Other Construction Material like Cement, Bitumen Steel etc.
  - Geotechnical Survey
4.2 Inventory and Condition Survey of Road Pavement / Cross Drainage Structure

The scope of improvement measures and economic justification thereon depend on the condition of the existing road and its associated inventory. To collect the inventory of the existing road and allied features of road and structures, inventory surveys have been carried out.

4.2.1 Road Inventory

While conducting Inventory Survey of Road the existing physical features and surrounding condition of the project road have been collected. The details are given in Chapter 2. (Annexure 2.1)

4.2.2 Pavement Condition Survey:

The visual survey of pavement condition has been carried out. The condition of the pavement surface varies from good to poor. The details of pavement condition survey have been given in Annexure 2.2. The pavement condition is good in about 36.60% length and fair to poor in the remaining 55% of length.

4.2.3 Topographic Survey

Topographic surveys have been carried out as per IRC: SP 19-2001, Manual for Survey, Investigation and preparation of Road Project and as per TOR, for the preparation of alignment plans, strip plans, longitudinal sections, cross sections and other details like drainage works, earth retaining structures, control points and reference pillars required in view of consideration of vertical and horizontal alignments. Surveys were carried out as follows:

(a) Plan metric Control

The co-ordinates of basic plan control pillars with reference pillar at 200m of size 300X300X450mm have been established by GPS at interval of 5 km all along the project highway. Between two control points, bench marks were fixed in interval of 250 m on pillars of size 150X150X450mm, which serve the purpose of starting
and closing bearings for Total Station Traverse. The data collected through GPS survey is presented vide Annexure 4.1.

(b) Height Control

Double tertiary levelling has been done along the entire stretch with precision automatic level connecting bench marks and reference control points established along the project road. The closing error were all seen to be below the tolerance limit of 0.12 mm/\sqrt{k}, where k is the length of the levelling line in km in between the starting and closing bench marks. The road cross section levels at an interval of 50m at centre line all along the length of project highway have been taken.

(c) Detailed Survey

The detail of project corridor area is up to minimum (building line) in case of urban area and 30m in case of realignments and open rural area. The limit was extended further in case of anticipated junction improvement as well as railway level crossings along the finalised centre line which were surveyed by running Total Station Traverse X, Y and Z coordinates of relevant points of survey to establish ground profile captured by this Total Station Traverse besides other details like electric / telephone poles, tree building, well, visible property line etc.

(d) Creation of DTM

Data collected through topographical survey clubbed with the findings of inventory surveys have been used to develop a Digital Terrain Model (DTM) in MX-Roads Software. Supplemented with the siting of important cross drainage structures along with their desired deck levels, horizontal and vertical profile of the project road has been finalised after the careful application of the relevant design standard.

Traverse and LS/CS Surveys were fed into computer to carry out the followings:

(i) Sort out the geometric (horizontal) deficiencies in the existing alignment.
(ii) Design the best fit centre line of the existing alignment considering all obligatory/nodal points with relevant design standards.
(iii) Examine the feasibility of proposed laning requirement within existing available ROW or proposal of bypass / realignment if any.
(iv) As far as possible obviate existing buildings, functional infrastructure facilities within the proposed ROW to minimise utility relocation.
(v) Examine each existing junction for its usefulness and determine the improvement measures.
List of TBMs are given in **Annexure 4.2**

Topographical Survey Report is at **Annexure 4.3**

### 4.3 Pavement Investigation

#### 4.3.1 General

Pavement Investigation comprise of carrying out Sub grade characteristics and strength, investigation of required Sub-grade and sub-soil characteristics, pavement composition by excavating trial pits of 1m X 1m X 1m size by the side of road edge in a stagger way at an interval of 2.50Km. to evaluate sub-grade strength by conducting DCP test and field density as well as collecting soil samples for various laboratory tests. The subgrade borrow soil and material report such as aggregates, sand cement etc. is at Table 4.3, 4.6 and para 4.5.2. Pavement condition surveys was done as per guide lines of IRC and for establishing the pavement strength Benkelman Beam deflection surveys were done at intervals as specified in ToR.

#### 4.3.2 Benkelman Beam Deflection (BBD) Test

##### 4.3.2.1 Pavement Structural Strength

There are several design methods used to determine the thickness of flexible overlay required. The most common is based on deflection testing and is widely used in India.

##### 4.3.2.2 Deflection Method

The structural strength evaluation by deflection method had been carried out by following scheme:

##### 4.3.2.3 Mainline Testing

In the mainline testing, BBD survey had been carried out at every 3km interval in a distance of 250m with ten deflection reading taken at every 25m all along the project road in staggered manner. The collected data had been analysed separately as per procedure given in IRC: 81-1997 to find out the Characteristic Deflection.
Characteristic deflection is calculated using the initial, intermediate and final readings according to the IRC Guidelines by applying temperature correction of 0.01 mm/0°C and seasonal correction as per codal provision.

Details analysis of Benkelman Beam Deflection survey for Main line is given in **Annexure 4.4**

### 4.3.2.4 Axle Load Survey

Axle load Survey was conducted at the same location where TVC was done i.e. at km 55.500 of SH-86C and Km. 2.000 of SH-86B. The Axle load Spectrum is generated by preparing a frequency distribution of axle loads. By multiplying the respective axle load with the equivalent factor, the vehicle damage factor (VDF) is estimated. The VDF so calculated are tabulated below:

**Table 4.1: Calculation of VDF**

<table>
<thead>
<tr>
<th>Location</th>
<th>Vehicle Type</th>
<th>Bus</th>
<th>Mini Bus</th>
<th>Mini LCV</th>
<th>LCV</th>
<th>2-Axle truck</th>
<th>3-Axle Truck</th>
<th>4-6 Axle vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH-86C KM-1+500</td>
<td>Bus</td>
<td>1.27</td>
<td>0.28</td>
<td>0.045</td>
<td>1.61</td>
<td>8.87</td>
<td>6.64</td>
<td>4.83</td>
</tr>
<tr>
<td>SH-86C KM-55+500</td>
<td>Bus</td>
<td>1.11</td>
<td>-</td>
<td>0.055</td>
<td>1.86</td>
<td>11.62</td>
<td>9.72</td>
<td>6.50</td>
</tr>
</tbody>
</table>

### 4.4 Sub Grade Investigations:

Investigations of existing sub grade were carried out to assess the adequacy of the existing pavement layers apropos to prevent sub grade strength so that the strengthening and reconstruction requirement can be established for the design traffic loadings. Objectives of investigations also included evaluation of the existing pavement composition; characteristics of existing sub grade for design of pavement by means of in-situ and laboratory tests as well as need for further investigations along the widened part / proposed new alignment.

The requirements of TOR were met through the following steps:

- Collection of minimum two samples of existing soil from every 5 km of the project or closer where changes in type of soil encountered.
• Determination of CBR at every three km. of the project or closers where change in soil type is encountered.
• Recording the existing pavement crust composition at every three km. intervals;
• Conducting tests on in-situ properties and characteristics of sub grade soils;
• Conducting laboratory tests on collected samples;
• Analysis of field and laboratory test results;
• Providing specific recommendation for existing pavement; and

Methodology

Test pit of size 1m X 1m X 1m investigations were carried out at the interface of main carriageway and earthen shoulder at every 2.5 km intervals in a staggered manner along the existing road alignment. Test pits were excavated manually upto sub grade level at the pavement shoulder interface. Approximately 50 kg of disturbed soil sample were collected from every trial pits and brought to the laboratory for determining index properties of soil and CBR.

4.4.1 Test pits for sub grade investigation

4.4.1.1 Test pits

Large pits of size about 1m x 1m X 1m were excavated at pavement shoulder interface, extending through the pavement layers down to the sub grade level. The sub grade soil was tested for in situ density test using sand replacement method as per IS:2720, Part 28. Dynamic Cone Penetration (DCP) test using Dynamic Cone Penetrometer was carried out from the top of subgrade to bottom level of sub grade to evaluate in situ sub grade strength. Sub grade soil sample (about 50 kg) was taken from each pit for detailed laboratory test.

Following test were carried out on the sub grade soil sample in the laboratory.

• Atterberg’s limits As per IS:2720, Part V - 1985
• Grain Size Analysis As per IS:2720, Part IV - 1985
• MDD As per IS:2720, Part VII- 1983
• Optimum Moisture Content As per IS:2720, Part VIII-1983
• CBR (4 days soaked) As per IS:2720, Part XVI-1987
4.4.2 Existing Pavement Composition

In order to meet TOR requirement detailed layer composition of the existing pavement was recorded from the test pits of 1m x 1m X 1m at dug out as detailed in 4.1.1 above. The test pits were excavated manually at pavement shoulder interface, dug up to the sub grade level. When sub grade layer reached thickness of various pavement layers were measured at exposed face and recorded.

During investigation of crust composition namely two layers were observed i.e. wearing coarse and base course while no separate sub base course was encountered in the majority of length. The wearing course consists of bituminous material termed as Bituminous Top (BT). The base course comprises of Water Bound Macadam (WBM). Existing pavement composition data is presented in Annexure 4.5. Summary of crust thickness is given in Table 4.2:

Table: 4.2 Summary of Existing Pavement Crust Thickness

<table>
<thead>
<tr>
<th>Type of Layer</th>
<th>Range of Pavement Thickness (mm)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
<td>Average</td>
</tr>
<tr>
<td>Bhawi – Pipar – Sathin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous Top</td>
<td>60</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Base Course</td>
<td>260</td>
<td>120</td>
<td>190</td>
</tr>
<tr>
<td>Total Thickness</td>
<td>320</td>
<td>140</td>
<td>230</td>
</tr>
<tr>
<td>Sathin – Palri-Ranawat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous Top</td>
<td>70</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Base Course</td>
<td>280</td>
<td>110</td>
<td>195</td>
</tr>
<tr>
<td>Total Thickness</td>
<td>350</td>
<td>140</td>
<td>245</td>
</tr>
<tr>
<td>LawariPiou – Khimsar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous Top</td>
<td>90</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Base Course</td>
<td>280</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>Total Thickness</td>
<td>370</td>
<td>150</td>
<td>260</td>
</tr>
</tbody>
</table>
Following **photographs** shows the crust of the project road:
4.4.3 Laboratory Test on Test Samples

Various laboratory tests are conducted on collected subgrade soil samples from pits. The summaries of laboratory investigation results have been compiled in Annexure 4.6 and described briefly in the following sections. The results and corresponding interpretation along with in-situ condition were influential to carry out the actual pavement design.

4.4.3.1 Classification

The soil samples have been primarily classified on the basis of Bureau of Indian Standards (BIS), which is based on Indian Standard Classification System. As per soil classification systems samples are classified as SM (Silty Sand), SM-SC (Silty Sand with little Clay), SM-GW (Silty Sand with Gravel), GM-SM (Gravel with Silty Sand) and test results are tabulated in Annexure 4.5.

4.4.3.2 Atterberg Limits

The test results reveal that the sub-grade soil is mostly non-plastic.

4.4.3.3 Compaction Characteristics

The collected soil samples from large test pits were compacted with different moisture content in the laboratory in order to obtain dry density v/s moisture content relationship. The method of compaction in accordance with IS: 2720(Part – 8) was used to determined Maximum dry density. The maximum dry density varies from 1.89gm/cc to 2.10gm/cc the results of compaction test are given in Annexure 4.6.

4.4.3.4 California Bearing Ratio (CBR) Test

Laboratory CBR test was conducted on samples obtained from Test Pit as per IS:2720 (Part-16) CBR moulds prepared by compacting the soil in five layers giving 15, 35 and 65 blows of heavy rammer, and soaked CBR value with swelling factor, was worked out. Quantity of water taken during remoulding CBR specimen is added equal to optimum moisture content. The dry density of soil compacted at various blows was determined. The laboratory CBR values of sub grade soils are given in Table 4.3:
Table 4.3: Summary of Test Results of Sub Grade Soil

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Limit %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic Limit %</td>
<td></td>
<td>Non Plastic</td>
<td></td>
</tr>
<tr>
<td>Plasticity Index %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDD gm/cc</td>
<td>2.10</td>
<td>1.89</td>
<td>2.00</td>
</tr>
<tr>
<td>OMC %</td>
<td>11.80</td>
<td>8.10</td>
<td>10.00</td>
</tr>
<tr>
<td>Soaked CBR %</td>
<td>29.60</td>
<td>15.90</td>
<td>22.75</td>
</tr>
</tbody>
</table>

4.4.4 Dynamic Cone Penetrometer test

Field CBR test using Dynamic Cone Penetrometer method was conducted to assess the in-situ CBR at sub-grade and below sub-grade level as per TRL-Road Note 8. The CBR value was determined for the various soil layers encountered by using Penetration v/s Number of Blows graph. Change in Slope, penetration v/s number of blows, indicates two layers in pavement composition. From this graph, layer thickness from respective slopes (penetration mm/blow) could be worked out.

DCP-CBR value was calculated using the following formula (TRL-Road Note 31 using 60° cone).

\[
\log_{10} (CBR) = 2.48 - 1.057 \times \log_{10} (\text{mm/blow})
\]

The DCP – CBR value was converted to an overall or equivalent CBR value using the material depth data. DCP-CBR varies from 10.47% to 18.61%. Comprehensive results of the DCP tests are computed in Annexure 4.5.

4.4.5 Investigations in natural ground along widening side and Realignment

Investigation for sub grade along the widening portion and proposed new alignment and carried out the same pattern as above and the test results had been complied and used for design of the road crust for the widening and new alignment portion of the project road.

4.5 Soil and Material Investigation

4.5.1 General

Widening of existing road, provision of realignment / new alignment and raising of existing pavement level is a basic requirement for any road improvement. For this purpose various construction materials are required. Therefore, material
investigation has been carried out to identify the availability of suitable materials within reasonable lead.

**Objective of Investigation**

- To identify the sources, like borrow area and aggregate quarry sites in the vicinity of the project road within reasonable lead;
- Location of borrow areas and quarries i.e. left or right and lead distance from nearest point on the project road;
- Approximate assessment of available quantity
- Quality of material and its suitability

**The Various Construction Materials are listed below:**

- Borrow soil
- Aggregate
- Locally available material like Fly ash, Waste slag etc.
- Granular material
- Sand

### 4.5.2 Soil and Material Investigation

**Borrow Soil (Embankment, Sub-Grade and Shoulders)**

Investigation of borrow area for road construction has been carried out to identify the potential sources of embankment fill material and sub grade material and to assess their general availability, nature and quantum of materials available for the project.

The project road is passing through a Plain terrain and abundant borrow soil is available along the project road within 1 to 10 km of lead. The sample of the borrow area has been collected and have been tested in laboratory. The average CBR is coming around 24% of these 4 borrow area. Details are given in Table 4.4:

**Table 4.4: MDD, OMC and CBR values for soils of sub-grade test pits**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Borrow Area No.</th>
<th>Laboratory Compaction</th>
<th>CBR Unsoaked</th>
<th>CBR Soaked (97%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>OMC (%)</td>
<td>MDD (Kg./cm³)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BR – 1</td>
<td>12.20</td>
<td>1.940</td>
<td>35.20</td>
</tr>
<tr>
<td>2</td>
<td>BR – 2</td>
<td>10.40</td>
<td>1.930</td>
<td>35.90</td>
</tr>
<tr>
<td>3</td>
<td>BR – 3</td>
<td>11.80</td>
<td>1.940</td>
<td>37.50</td>
</tr>
</tbody>
</table>
Aggregate Quarry

Aggregate stone is basic ingredient in road construction investigation of quarry area has been carried out to ascertain the potential sources of aggregate which can be used for the construction of different pavement layers like Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), Bituminous Macadam (BM), Wet Mix Macadam (WMM), Granular Sub-base and Sand for cement concrete works, GSB etc. Main source of aggregate is quarry at Sewki about 30 km from Bhopalgarh and Achhjai about 35 Km. from Merta City. Sufficient quantity of material is available.

The sample of aggregates from the above said Quarries have been collected and tested in laboratory and found suitable for sub-base / base material.

Table: 4.5 - Summary of Test Results of Aggregates

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location / Chainage</th>
<th>Specific Gravity</th>
<th>Water absorption (%)</th>
<th>Impact Value</th>
<th>Agg. Crushing Value</th>
<th>Abrasion Value</th>
<th>Flakiness Index %</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Achhjai</td>
<td>2.7</td>
<td>0.50</td>
<td>24.23</td>
<td>25.23</td>
<td>39.96</td>
<td>9.85</td>
<td>44.05</td>
</tr>
<tr>
<td>2</td>
<td>Achhjai</td>
<td>2.68</td>
<td>0.80</td>
<td>25.83</td>
<td>39.28</td>
<td>39.28</td>
<td>14.70</td>
<td>31.20</td>
</tr>
<tr>
<td>3</td>
<td>Sewaki</td>
<td>2.7</td>
<td>0.60</td>
<td>20.50</td>
<td>-</td>
<td>38.40</td>
<td>9.80</td>
<td>25.20</td>
</tr>
</tbody>
</table>
Granular Material

Granular material is used for the drainage layer (GSB) in the pavement crust. This layer is laid up to the formation width of the pavement for the effective drainage so as to improve the performance of the pavement and to extend the service life of pavement. Granular material used in the GSB layer should have liquid limit and plasticity index restricted to 25% to 6% respectively. In case of non-availability of suitable granular material in vicinity of project area within the reasonable lead distance, Soil, Sand and Aggregate are to be blended with suitable proportion (preferably 60:10:30) so as to achieve specified test value. Granular material can be obtained from Luni River or made by blending (Soil + sand + Aggregates) by obtaining the aggregates from Achhjai / Sewaki quarry.

“The results of the material to be obtained from Luni river / stone quarries are given in table 4.5 & 4.6.

Sand

Sand sample have been collected from the Luni River quarry and Jogri river 8-10Km. from Pipar and Luni river 25Km. from Merta City. The results are summarised below:

<table>
<thead>
<tr>
<th>Location/Chainage</th>
<th>Fineness Modulus (%)</th>
<th>Water Absorption (%)</th>
<th>Bulking %</th>
<th>Silt Content (%)</th>
<th>Specific Gravity</th>
<th>Modified Proctor Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luni River</td>
<td>2.94</td>
<td>0.80</td>
<td>6.35</td>
<td>8</td>
<td>2.64</td>
<td>1.85</td>
</tr>
</tbody>
</table>

Geotechnical Investigation

Geotechnical investigations have been got carried out at the location of proposed ROB. A plan showing the locations of proposed borings was submitted to the Project Director / Authority vide letter No.: 13/6967/E/FC/GU/3042 dated 10th July 2015 (copy attached at Annexure 4.5). As per the above proposal one bore hole was taken at the location of each abutment / pier well depth of boring as 30 m / 10 m respectively.

Sub Soil investigation has been carried out as per guidelines vide IRC 78-2000. Bore hole of 150mm diameter drilled by Augur / Rotary boring resisted by using Nx size in all type of
refusal strata or 3.0 m in hard rock where core recovery > 50% using suitable method of drilling and collecting core in core boxes.

Standard penetration tests in bore holes have been conducted as per IS:2131, 1981 in all types of soils during boring activity at site at every 1.50 m interval or at every change of strata whichever occur earlier. The blow counts for SPT terminated when combined blow count exceed 100 (Refusal) for the last 300 mm penetration of the sample.

A detailed report on Geo-technical investigation for the construction of ROBs is enclosed (Annexure I).

4.5.3 Water for construction purposed

Ground water and surface water in the vicinity of the project road is considered as a source of water. However, the water for construction can be made available by constructing bore at plant site.

Water samples from rivers / reservoir and hand pumps were collected. It is noted that almost every village along the project road water is being extracted from bore wells which is found to be of potable quality. From all these it is concluded that adequate quality of suitable water will be available for implementation of project works.

4.5.4 Fly ash

Use of flyash has not been proposed on the project due to its non-availability within a distance of 100 Km. of the Project Highway.

4.5.5 Manufacture Materials

Bitumen materials:
The nearest refinery is situated in Mathura which is about 500 km from mid of the project site.

Steel and Cement:
Steel and Cement is available in the open market and these can be procured easily from there.

4.6 Hydrological and Hydraulic Study and Geotechnical Investigations and Sub Soil Exploration
4.6.1 Hydrological and Hydraulic Study

The objective of the hydrological and hydraulic study is to determine the required number and sizes of the drainage structures so as to allow the design discharge of the river / stream to pass safely through the opening and to check whether waterway of the existing structure is sufficient to transmit the flow without risk.

The hydrological and hydraulic study for the project is based on:

- Topographic survey data of the existing structures
- Topographic data and maps of river, upstream and downstream
- Rainfall pattern of the project area
- Study of the characteristics of the catchments area, HFL from local enquires and tell-tale marks and hydraulic conditions at the existing structures.

The available topographic maps of the influence area on the various scales of 1:50,000 and 1:2,50,000 have been studied to identify the number of valleys crossing the alignment of the road, to broadly assess the number of drainage structures and demarcate their catchment area so as to assess the run off characteristics. Hydrological reconnaissance survey has been carried out to properly identify and match the existing structures with proper valley location, to finalise the number of additional structures required, to ascertain the pattern of the area. Information on past floods and their effects on existing structures will be collected from records, local officers and nearby residents of the area. Design discharge and high flood level would be established using these data and information collected from field and their detailed interpretation and analysis.

Adequacy of the existing structures has been arrived corresponding to the Design HFL and the clearance / freeboard required as per the IRC guidelines. For the additional new structures required, the linear waterway has been provided as per the design discharge keeping view width of the existing stream.

The improved rational methods have been used to determine discharges at the culvert locations where catchment areas could be marked from topo-sheets. The adequacy of most of the slab culverts has been checked assuming flow through culvert as open channel flow and assuming suitable velocity through
culverts based upon stream characteristics. The adequacy of the pipe culverts acting as balancer has been checked taking inlet submerged condition and runoff coming from road and adjacent area.

4.7 Inventory and Condition Survey of structures

4.7.1 Inventory of Existing Level Crossing / ROB/RUB

There is one level crossing on the project highway. At present there is no proposal to construct ROB at this location.

4.7.2 Cross-Drainage Structures

In the entire stretch of project road between Bhawi-Pipar-Khimsar a total of (6 culverts + 17 causeways) CD structures exist. These comprise pipe culvert, slab culvert and causeway. The detail of C.D. Structure is given in Annexure 2.3.

Summary of different types of culverts and their numbers in the whole project highways are indicated as follows:

Table: 4.7 – Cross Drainage Structure

<table>
<thead>
<tr>
<th>Location</th>
<th>Pipe</th>
<th>Slab</th>
<th>Causeway</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhawi – Sathin</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Sathin – Palri-Ranawat</td>
<td>-</td>
<td>2</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Lawari – Khimsar</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>