Chapter 3

Development of in-situ asphalt pavement and concrete bridge deck testing facility for controlled field investigations

3.1. Introduction

Pavement condition evaluation faces numerous challenges due to variations in field conditions from one place to another and uncertainty in the rate and mode of pavement deterioration. Accurate identification of subsurface flaws and anomalies of pavements in unknown and uncontrolled field conditions is one such challenge. Visual surveys often are not enough for such defect detection and are required to be supplemented with destructive testing methods. However, destructive testing such as coring or boring is not a feasible and economical alternative. Therefore, Non-Destructive Testing (NDT) methods offer several merits in such cases but they require technical expertise in order to understand the obtained results, which limits their usage at a network level. To promote NDT on a wider scale, studies should be conducted first to gain the understanding and technical knowledge of the technology as well as the potential outputs under controlled conditions. After gaining an experience of evaluating such pavement with flaws under controlled conditions, its replication in uncontrolled field conditions becomes easier. Few studies in recent past conducted by authors (Celaya et al., 2009; Heitzman et al., 2013; Simonin et al., 2015a, 2015b, 2016) evaluated NDT methods on asphalt pavement sections specifically constructed with debonding agents (clay slurry, talcum powder, grease, oily paper, textile, etc.) placed between different asphalt lifts at predetermined locations to simulate different degrees of debonding. Similarly, studies to assess performance of NDT technologies for detection of common internal flaws in bridge decks were performed by fabricating bridge deck slabs or concrete blocks with artificially created defects (Gucunski et al., 2013; Hiasa et al., 2018; Yehia et al., 2007).

In order to undertake the studies identified in Chapter 1 to assess the utility of Infrared Thermography (IRT) and combination of NDT methods for subsurface defect detection, the in-situ testing facilities comprising asphalt pavement test section and concrete bridge deck were designed and constructed. Construction of these testing platforms facilitates a better understanding of subsurface pavement defects, their identification, reasons, and locations of their occurrence with varying extent of deterioration. Development of the in-situ asphalt pavement testing facility involved pavement test section containing various degrees of bonding and underground anomalies or buried objects along with the in-situ pavement temperature measurement system. Fabrication of concrete bridge deck involved bridge deck with simulated defects, including delaminations (DL), voids (V), corroded rebars (CR), and vertical cracks (VC).

This chapter explores various aspects of planning, design, and construction of the in-situ testing facilities for subsurface defect detection under controlled field conditions. The chapter concludes with lessons learnt with the progress of construction activities. The following sections discuss the mobilization of the construction activity, mix design, geometry details of test sections, and actual construction process.

3.2. Mobilization of the construction activity

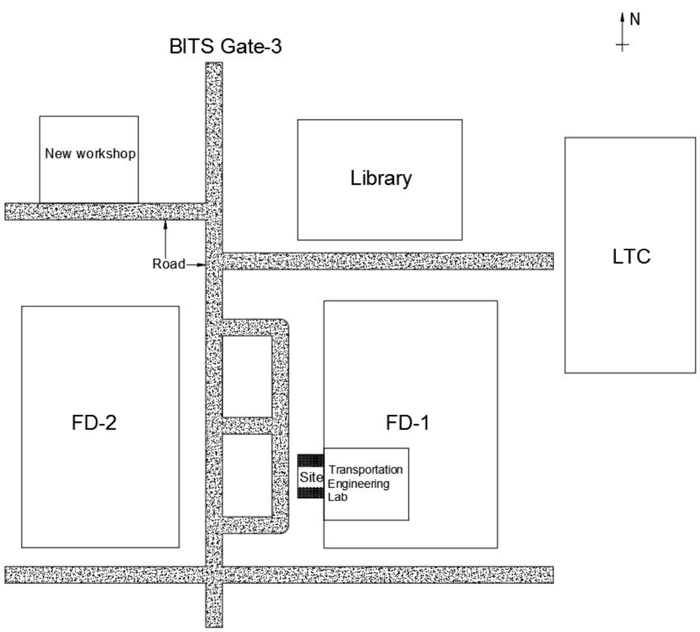
In the first step to mobilize the construction activity, the competent authorities of the Birla Institute of Technology and Science (BITS) Pilani were approached to take approval for the construction project and a suitable location for the construction within the campus was identified. The next step was the construction of test sections. The work of asphalt test section was taken up by a construction company from Jhunjhunu, Rajasthan along with local contractor and for bridge deck by Tricon Buildwell, New Delhi. Thorough review of literature helped to decide the thickness of asphalt layers and bridge deck, dimensions of these sections and their individual blocks for introducing various conditions, and design of reinforcement in concrete bridge deck.

To maintain the precision during construction in a controlled manner and avoid unnecessary delays during the construction activities, the sequence and details of this specialized construction were decided well in advance. Materials for bonding and anomaly conditions of asphalt test section were procured locally with the help of Workshop facilities available at BITS Pilani. Materials to simulate delamination, void and vertical crack in concrete bridge deck were also procured locally with the help of Workshop facilities available at BITS Pilani. Corroded rebars were procured from demolished old building material in BITS Pilani.

3.3. Development of in-situ asphalt pavement test section

3.3.1. Location and geometry of the test section

The site for asphalt pavement test section construction is located inside BITS Pilani – Pilani campus, near transportation engineering lab of FD-1 block. The location is chosen so as to get enough solar exposure for maximum duration in a day to successfully conduct thermal testing. The schematic diagram of the location is shown in Figure 3.1.



(a) Schematic of test site **(b) Actual test site**

Figure 3.1. Location of the test section at BITS Pilani- Pilani campus

The design for the controlled field asphalt pavement test section is illustrated in Figure 3.2. The overall dimensions of the section is 700 cm × 200 cm with actual testing area of 660 cm × 180 cm (refer Figure 3.2). The 150 mm thick section is constructed as an overlay on an existing asphalt pavement.

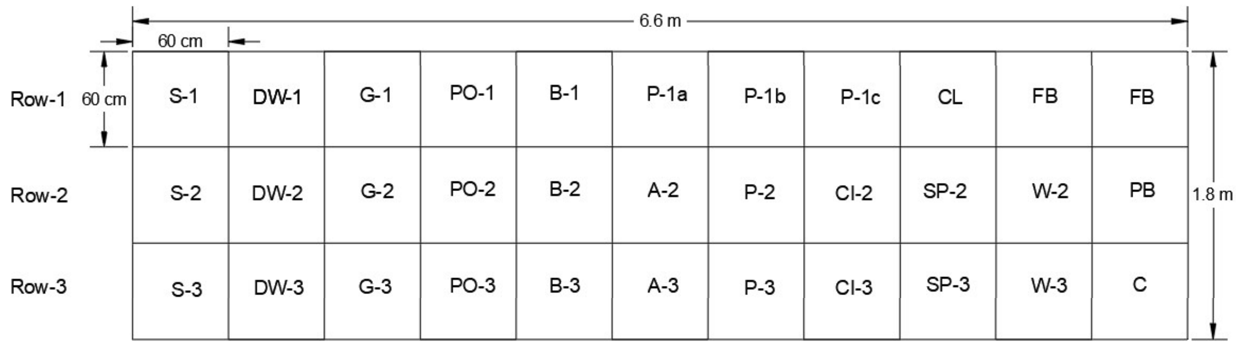


Figure 3.2. Design of asphalt pavement test section constructed at BITS Pilani- Pilani campus

The test section has been further divided into blocks of 60 cm × 60 cm, resulting in eleven blocks longitudinally and three blocks laterally, with a total of thirty-three blocks. Various bonding and anomaly conditions were introduced in these blocks. The nomenclature of the blocks was done according to the purpose they serve and the layer on which they were placed. Bonding conditions include sand (S), dust along the wheel paths (DW), grease (G), polythene (PO), bentonite slurry (B), full bond (FB), and partial bond (PB). Objects laid for anomaly identification included aluminum plate (A), cast-iron L-section (CL), cast-iron plate (C), wood block (W), hollow PVC pipe (P), hollow steel pipe (SP) and hollow cast-iron pipe (CI). Table 3.1 presents the dimensional details of bonding conditions and anomalies.

Table 3.1. Details of bonding and anomaly conditions used in asphalt pavement test section

Block	Material	Length (cm)	Breadth (cm)	Thickness (cm)	Diameter (cm)
S-1,S-2,S-3	Sand	60	60	-	-
DW-1,DW-2, DW-3	Dust along wheel path	60	60	-	-
G-1,G-2,G-3	Grease	60	60	-	-
PO-1,PO-2,PO-3	Polythene	60	60	-	-
B-1,B-2,B-3	Bentonite slurry	60	60	-	-
FB	Full bond	60 × 2	60	-	-

Block	**Material**	**Length (cm)**	**Breadth (cm)**	**Thickness (cm)**	**Diameter (cm)**
PB	Partial bond	60	60	-	-
A-2,A-3	Aluminum plate	15	15	0.3	-
C	Cast-iron plate	38	38	0.5	-
CL	Cast-iron L-section				
W-2,W-3	Wood block	25	11	4.5	-
P-1a,P-1b,P-1c	Hollow PVC pipe	8	-	-	5.5
P-2,P-3		18	-	-	5.5
SP-2,SP-3	Hollow steel pipe	12	-	-	5.0
CI-2,CI-3	Hollow cast-iron pipe	29	-	-	6

3.3.2. Construction process

The dense graded bituminous mix was used for the construction with VG 30 viscosity grade (IS 73:2006, 2006) asphalt binder. To find out the optimum asphalt binder content (5% in this case), Marshall mix design was done. During the preparation and laying of the mix, the temperature was continuously monitored with the help of thermometers. Prior to laying the overlay, three cores of existing pavement are extracted to place the anomalies at certain depth and to know about the existing pavement. The existing pavement was found to have two asphalt layers of 40 mm and 30 mm thickness. The surface of existing pavement was thoroughly cleaned to make it free from dust, debris and other loose materials, before starting the overlay construction. Three Hot-Mix Asphalt (HMA) lifts of 50 mm each have been laid and properly compacted using smooth wheel roller. The three lifts provided three interfaces at depths of 50 mm, 100 mm and 150 mm, and facilitated the study of bonding conditions and anomaly detection at different depths. The design of the test section was done to simulate one fully bonded condition, two partially bonded conditions and four debonded conditions. The condition of fully bonded was ensured by using optimum amount of tack coat (FB); partially bonded conditions using DW and non-uniform application of tack coat (PB); and use of bond breakers, viz., S, G, PO, and B ensured no bond or debonded condition. These represent a majority of bonding conditions encountered within the top 120-150 mm of asphalt pavements. Six different buried objects for anomaly testing included A, CL, C, W, P, SP, and CI (refer Table 3.1 for their dimensions). The buried objects are also chosen that may come across in real field conditions and cause local failure of asphalt layer.

Introduction of various bonding and anomaly conditions:

To implement the specialized construction, following procedure was adopted:

Step 1: Boundaries of various blocks were marked using chalk on the existing pavement section (refer Figure 3.3). Coring was performed over the selected blocks marked as P-1a, P-1b, P-1c in Figure 3.2. The stages of coring operation and cores obtained are shown in Figure 3.4.

Step 2: Hot asphalt tack coat was applied at the rate of 0.25-0.30 kg/m^2 (CPWD, 2009) except over the debonded areas.

Step 3: Materials to achieve S-3, DW-3, G-3, PO-3 and B-3 bonding conditions were introduced suitably at their locations (along row-3). Three PVC pipes (P-1a, P-1b, P-1c) were buried, beneath the existing pavement surface at the cored locations (refer Figure 3.2, 3.5 and 3.6).

Step 4: Different anomaly conditions were introduced at the corresponding blocks (A-3, P-3, CI-3, SP-3, W-3, C) as shown in Figure 3.7. Guide marks using paint were used to know the precise location of the anomalies.

Step 5: The first 50 mm lift of HMA was laid and spread uniformly. The layer was rolled to achieve the desired degree of compaction.

Step 6: The boundaries of various blocks along row-2 were marked on the top of first HMA lift using guide rods according to the dimensions. To achieve PB bonding condition, asphalt binder was heated and kept ready.

Step 7: After the first lift was cooled down, the tack coat was applied and the various bonding and anomaly conditions were introduced along row-2 (refer Figure 3.8).

Step 8: The construction of another HMA layer was continued resulting in total thickness of 100 mm at this stage of construction.

Step 9: To achieve FB and PB bonding condition, asphalt binder was heated and kept ready. Materials for bonding and anomaly conditions were kept ready. The boundaries of various blocks along row-1 were marked on the top of second HMA lift.

Step 10: The final HMA lift was laid after the cooling down of second layer (refer Figure 3.9), and compaction was done using smooth wheel roller (refer Figure 3.10).

Step 11: The desired 150 mm thick section was constructed and the total thickness of the overlay remained same for the entire test section. Seal coat was then applied on the top as shown in Figure 3.11. Figure 3.12 shows various stages of construction of the test section.

Step 12: Finally, the top surface was marked with paint for the locations of bonding and anomaly conditions with the help of guide marks (refer Figure 3.13). Figures 3.3 to 3.13 shows the actual pictures of construction of in-situ asphalt pavement test section.

Figure 3.3. Initial demarcation of blocks on existing asphalt pavement before laying of bonding/anomaly conditions

(a)

(b)

(c)

(e)

Figure 3.4. Coring operations and cores obtained from existing asphalt pavement

(a) Sand (S) **(b) Dust along wheel path (DW)**

(c) Grease (G) **(d) Polythene (PO)**

(e) Bentonite slurry (B)

Figure 3.5. Different bonding conditions introduced to various blocks of in-situ asphalt pavement test section

Figure 3.6. PVC pipes placed at the cored locations

Figure 3.7. Different anomaly conditions introduced to various blocks of in-situ asphalt pavement test section

Figure 3.8. Placement of different bonding and anomaly conditions along row-2

Figure 3.9. Placement of different bonding and anomaly conditions along row-1

Figure 3.10. Compaction of constructed test section using smooth wheel roller

(a)

(b)

Figure 3.11. Preparation and application of seal coat

(a) **(b)** **(c)** **(d)**

Figure 3.12. Various stages of test section construction

Figure 3.13. Constructed in-situ asphalt pavement test section

3.4. Development of in-situ concrete bridge deck slab

3.4.1. Location and geometry of the slab

The site for fabrication of concrete bridge deck is located inside BITS Pilani – Pilani campus, near new academic block. The schematic diagram of the location is shown in Figure 3.14.

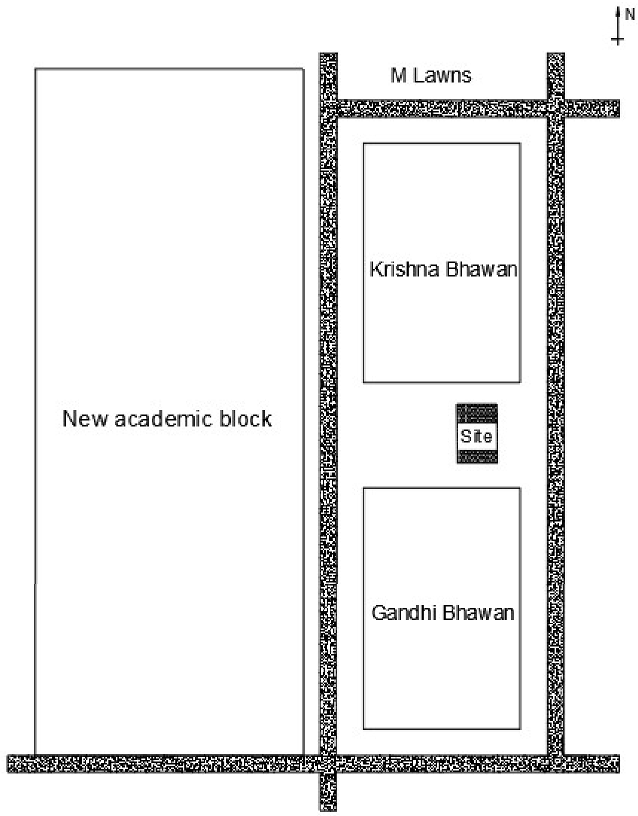


Figure 3.14. Location of concrete bridge deck slab at BITS Pilani – Pilani campus

A concrete bridge deck slab of lateral dimensions 300 cm × 200 cm and 20 cm thickness was fabricated and supported on brick walls. The slab was built with two mats of reinforcement consisting of 12 mm diameter steel bars spaced 200 mm center-to-center in both longitudinal and transverse direction. The top and bottom concrete cover of 40 mm was provided. Since the analysis for traffic loading and unloading is not the part of this study, therefore the provision of reinforcement was considered on the basis of minimum reinforcement criteria with two mats provided, as per IRC specifications (IRC 112, 2011). The slab was simulated with twenty delaminations, a corroded reinforcement mat, two voids, and two vertical cracks. The dimensions for each of these simulated defects are chosen similar to the most commonly occurring in field. One-third area of the slab (200 cm × 100 cm) was kept free from any defect in order to compare the conditions of sound and defected area. All the defects were placed at their pre-defined location before laying the concrete. The concrete mix was prepared on site and placed. The approximate defect distribution is depicted in Figure 3.15. Table 3.2 summarizes the details of these defects.

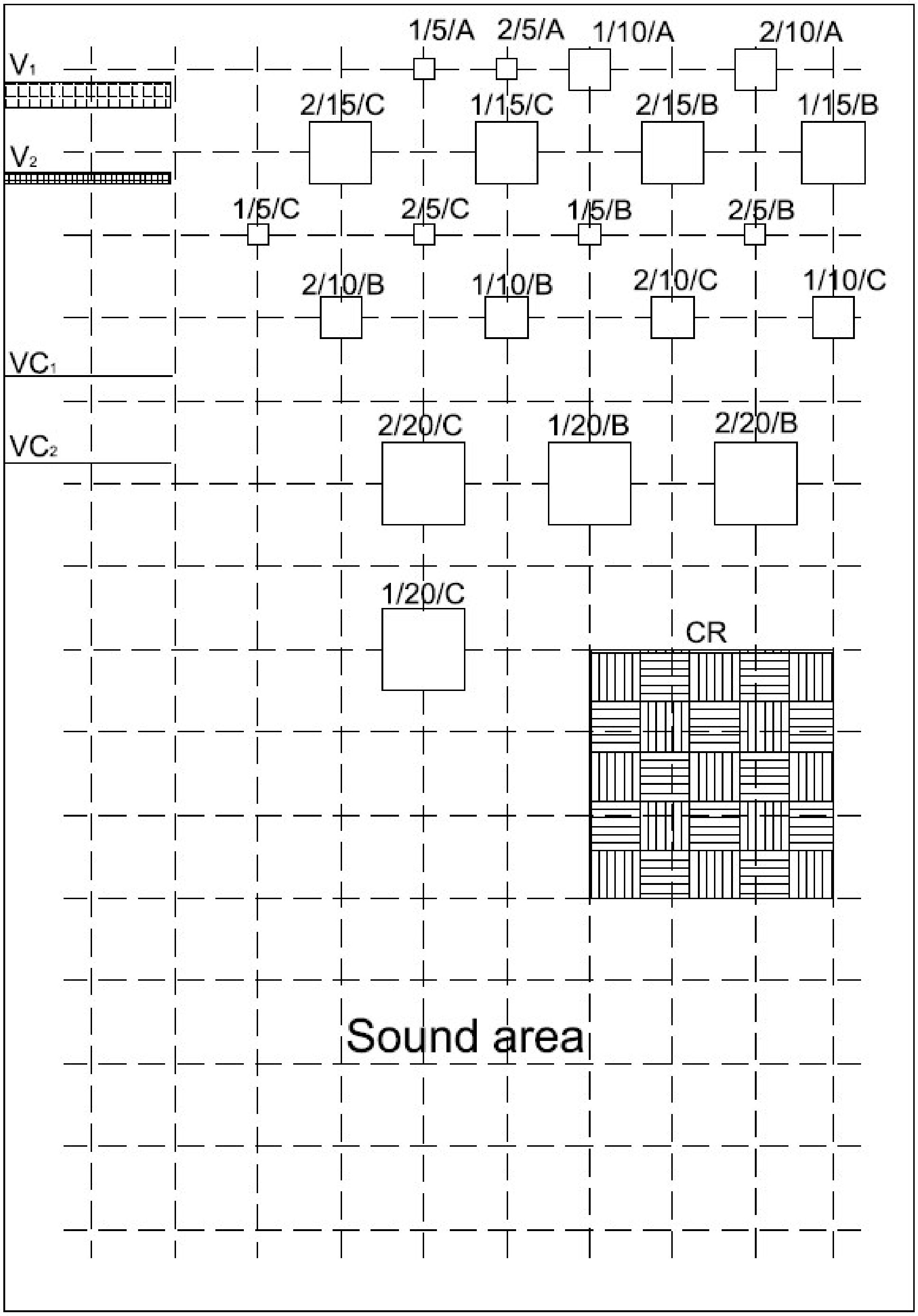


Figure 3.15. Design of concrete bridge deck slab at BITS Pilani – Pilani campus and defect distribution

Table 3.2. Details of simulated defects in concrete bridge deck slab

Type of defect	Code	Size (cm)	Thickness (mm)	Diameter (mm)	Depth from surface (mm)
Void	V_1	40	-	60	20
	V_2	40	-	25	80
Vertical crack	VC_1	40	1	-	20
	VC_2	40	2	-	60
Corrosion	CR	60 × 60	-	-	40
Delamination	DL-1/5/A	5 × 5	1	-	25
	DL-2/5/A	5 × 5	2	-	25
	DL-1/10/A	10 × 10	1	-	25
	DL-2/10/A	10 × 10	2	-	25
	DL-1/15/B	15 × 15	1	-	40
	DL-2/15/B	15 × 15	2	-	40
	DL-1/15/C	15 × 15	1	-	136
	DL-2/15/C	15 × 15	2	-	136
	DL-1/5/C	5 × 5	1	-	136
	DL-2/5/C	5 × 5	2	-	136
	DL-1/5/B	5 × 5	1	-	40
	DL-2/5/B	5 × 5	2	-	40
	DL-1/10/B	10 × 10	1	-	40
	DL-2/10/B	10 × 10	2	-	40
	DL-1/10/C	10 × 10	1	-	136
	DL-2/10/C	10 × 10	2	-	136
	DL-1/20/B	20 × 20	1	-	40
	DL-2/20/B	20 × 20	2	-	40
	DL-1/20/C	20 × 20	1	-	136
	DL-2/20/C	20 × 20	2	-	136

3.4.2. Construction process

Concrete of grade M30 as per IRC: 112 (2011) specifications was adapted for deck construction. After the concrete placement, water curing was done to the slab for seven days. Six cubes were also casted and tested for compressive strength. The 28-day compressive strength was obtained to be 34 MPa.

In actual field conditions, delaminations and cracks of 1-2 mm thickness are found. Therefore, to replicate the field conditions, foam sheets of 1 mm and 2 mm thickness were cut in desired dimensions (refer Table 3.2) to create artificial delamination. The purpose to select foam for simulating delamination is due to the fact that the value of thermal conductivity for foam is 0.033 $W.(mK)^{-1}$ which is very close to that of air (0.024 $W.(mK)^{-1}$). Furthermore, due to time and fund constraints to build accelerated corrosion on original steel bars, the corroded bars were obtained from scrap of demolished old structures in BITS Pilani – Pilani campus. Voids were constructed using the PVC pipes (60 mm and 25 mm diameter). Thin strips were cut from steel sheets (1-2 mm thick) to create cracks artificially.

Introduction of various bonding and anomaly conditions:

To implement the specialized construction, following procedure was adopted:

Step 1: Foam pieces, PVC pipes, and steel strips were kept ready to create artificial defects.

Step 2: The shuttering was placed in the required dimensions and mats of reinforcement were laid with 40 mm cover (refer Figure 3.16).

Step 3: Mat of corroded rebars was prepared and fixed suitably with the normal reinforcement at one end of the fabricated deck. PVC pipes and steel strips were greased to ensure their easy removal and were fixed at the desired location before laying concrete, as shown in Figure 3.17.

Step 4: Concrete mix of required grade was prepared on site in tilting drum type concrete mixer (refer Figure 3.18).

Step 5: Concrete was poured till the level of bottom reinforcement mat (approximately 136 mm deep from surface) and compacted using needle vibrator. Delaminations to be created at this level were introduced using foam pieces at their respective locations.

Step 6: Concrete was again poured till the level of top reinforcement mat (approximately 40 mm deep from surface) and the delaminations at this level were introduced, as shown in Figure 3.19.

Step 7: Another set of delaminations to be located at the depth of 25 mm from the surface were introduced by foam pieces, and the concrete was poured to cover the entire area of the slab. Final finish was given to the slab as shown in Figure 3.20 and the slab casting was completed (refer Figure 3.21).

Step 8: After 5-6 hours of casting, the PVC pipes and steel strips were pulled and removed to create voids and cracks in the slab, respectively.

The shuttering was removed and curing was done for the required number of days for the concrete to achieve its full strength.

Figure 3.16. Reinforcement mats laid for the construction of concrete bridge deck slab

(a) PVC pipes and steel strips **(b) Mat of corroded rebars**

Figure 3.17. Shuttering with induced defects before casting slab

(a) **(b)**

Figure 3.18. On-site preparation of concrete mix in tilting drum type concrete mixer

(a) **(b)**

Figure 3.19. Placing of foams to induce delaminations while concreting

Figure 3.20. Final finishing while casting slab

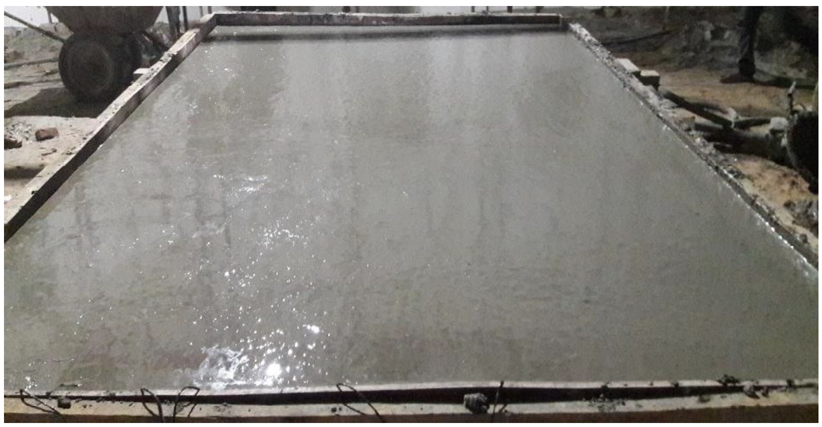


Figure 3.21. Casted bridge deck slab

3.5. Concluding remarks

This chapter has outlined the development process of two in-situ testing facilities for the defect detection studies under controlled field conditions. It also discusses about different phases of construction process. These developed facilities are then used further in this thesis to conduct various studies on bonding and anomaly detection using different non-destructive tests. These are discussed one by one in Chapters 4 and 5.