

CC9 Pre-traffic GPR Calibration Test Plan

Based on the analysis of CC9 baseline Ground Penetrating Radar (GPR) survey data, it was found from 900 MHz ground-coupled antenna that the thickness difference was more than 0.5-inch between the mean predicted vs as-built thickness for asphalt layer (P-401MR) on many test items, while the thickness difference from 2 GHz air-coupled antenna was relatively low, i.e., 0.1 – 0.6-inch. It was speculated that this discrepancy related to the inaccuracy in signal velocity (or, dielectric constant) in P-401MR, which was determined from the ‘Ground-Truth’ information for ground-coupled antenna and metal-plate calibration for air-coupled antenna. Following tasks are proposed:

1. GPR survey with 900 MHz and 2 GHz antenna to capture asphalt layer interface, signal amplitudes, and 2-way travel time on pre-selected locations
2. After completion of GPR survey, extract P-401MR cores from the designated/marked locations to obtain as-built thickness
3. Data analysis including calibration of signal velocity, thickness prediction, and accuracy assessment

On-Site Tasks

GPR Survey

Detailed information regarding the survey layout is summarized in Table 1.

- a) Conduct longitudinal surveys with 2 GHz antenna on:
 - (i) Thick P-401MR: ‘LFC-3N and -3S + Transition Area, T-3N/-3S’ (see Figure 1).
 - (ii) Thin P-401MR: ‘LFC-5N and -5S + Transition Area, T-5N/-5S’ (see Figure 2).
- b) Conduct transverse surveys with 900 MHz antenna on:
 - (i) Thick P-401MR: ‘LFC-3N and -3S + Transition Area, T-3N/-3S’ (see Figure 1).
 - (ii) Thin P-401MR: ‘LFC-5N and -5S + Transition Area, T-5N/-5S’ (see Figure 2).
- c) Conduct additional surveys using both antenna in static mode directly at the coring locations under both thick and thin asphalt layers (i.e., red markers as shown in Figure 1 and 2).
- d) Conduct static mode surveys using 900 MHz antenna on metal plate by placing it on pavement surface at locations ‘C1’ and ‘C5’ to verify the time-zero reference along surface.
- e) Conduct ‘Metal Plate Calibration’ test using 2 GHz air-coupled antenna by performing ‘Time Scan Mode’ survey on a metal plate with clean and dry surface (i.e., corroded surface is not acceptable). Even though this was included in the baseline test, it is recommended to conduct again:
 1. Follow manufacturer’s guideline, every time before/after the field survey
 2. Account for any changes in signal amplitudes due to variation in humidity & moisture

Coring

Detailed information regarding the coring locations is summarized in Table 2.

- a) Extract 4-inch diameter P-401MR cores from the Transition Area(s) on both North and South sides (i.e., T-3N, T-3S, T-5N, and T-5S), as shown in Figure 1 and 2.

b) Take measurement of asphalt layer thickness.

Table 1. GPR Survey Layout

GPR System	Survey Mode	Survey Line/Point	Station	Offset (feet)
Cart-Mounted (900 MHz)	Continuous (Transverse)	T1	1+50	Start: -26.66; End: 26.66
		T2	1+69	Start: -26.66; End: 26.66
		T3	2+70	Start: -26.66; End: 26.66
		T4	2+90	Start: -26.66; End: 26.66
	Static (on core locations)	C1	1+69	-20.25
		C2	1+69	-17.25
		C3	1+69	17.25
		C4	1+69	20.25
		C5	2+90	-20.25
		C6	2+90	-17.25
		C7	2+90	17.25
		C8	2+90	20.25
Van-Mounted (2 GHz)	Continuous (Longitudinal)	L1	Start: 1+20; End: 1+72.5	-20.25
		L2	Start: 1+20; End: 1+72.5	-17.25
		L3	Start: 1+20; End: 1+72.5	17.25
		L4	Start: 1+20; End: 1+72.5	20.25
		L5	Start: 2+40; End: 2+95	-20.25
		L6	Start: 2+40; End: 2+95	-17.25
		L7	Start: 2+40; End: 2+95	17.25
		L8	Start: 2+40; End: 2+95	20.25
	Static (on core locations)	C1	1+69	-20.25
		C2	1+69	-17.25
		C3	1+69	17.25
		C4	1+69	20.25
		C5	2+90	-20.25
		C6	2+90	-17.25
		C7	2+90	17.25
		C8	2+90	20.25

Note 1: Total of 12 data files from continuous survey.

Note 2: Total of 16 data files from static survey on core locations

Note 3: 2 data files from survey on metal plate (LFC-3N and -5N) and 1 data file from 'Metal Plate Calibration' test

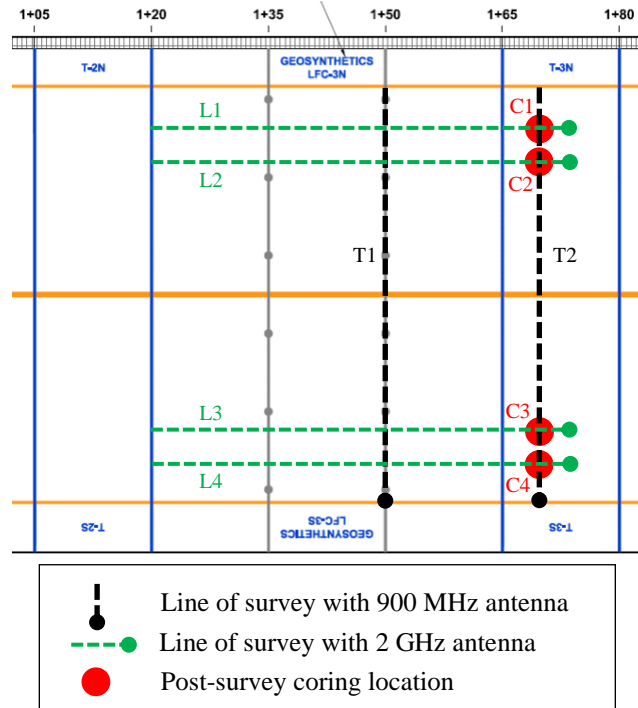


Figure 1. GPR Survey Layout and Coring Locations on LFC-3N and -3S + Transition Area (T-3N and -3S)

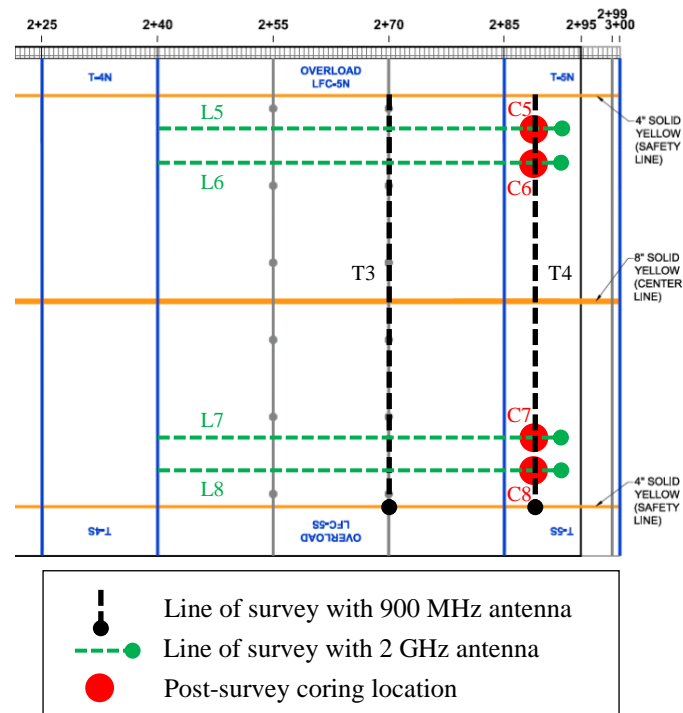


Figure 2. GPR Survey Layout and Coring Locations on LFC-5N and -5S + Transition Area (T-5N and -5S)

Table 2. Coring Locations

Side	Transition	Core ID	Core Diameter (inch)	Station	Offset (feet)
North	T-3N	C1	4	1+69	-20.25
		C2	4	1+69	-17.25
South	T-3S	C3	4	1+69	17.25
		C4	4	1+69	20.25
North	T-5N	C5	4	2+90	-20.25
		C6	4	2+90	-17.25
South	T-5S	C7	4	2+90	17.25
		C8	4	2+90	20.25

Off-Site Tasks

Post-Processing

- Post-process GPR images to track the surface and bottom of asphalt layers.
- Determine the ‘2-way travel time’ in asphalt layer.

Signal Velocity

- Determine signal velocity for both antenna from the ‘2-way travel time’ and measured thickness from cores, i.e., $v = 2h/t$, where h = measured core thickness; and t = 2-way travel time in asphalt layer. Note that the static mode (on core location) GPR survey data will be used for this analysis.
- Determine dielectric constant $\varepsilon = (c/v)^2$, where c = signal velocity in air (= 11.8 in/ns); and v = signal velocity in asphalt layer as determined in Step (a).
- For both thick and thin asphalt layers, evaluate the consistency of ε within test item, i.e., Core C1 vs C2, C3 vs C4, C5 vs C6, and C7 vs C8, and between the test items to examine: (i) any change in ε due to the slow-roll test; and (ii) feasibility of integrating ε to thickness prediction, which is determined from core locations that may not be aligned with the survey line.

Thickness Prediction

- Determine asphalt layer thickness from the ‘2-way travel time’ and signal velocity (as determined in previous phase): $h = vt/2$. Note that the continuous mode (i.e., transverse survey for 900 MHz and longitudinal survey for 2 GHz) GPR data will be used for this analysis.
- Evaluate thickness distribution to confirm: (i) the level of improvement in thickness prediction; and (ii) consistency of thickness distribution within test item (i.e., survey line L1 vs L2, L3 vs L4, T1 vs T2, and T3 vs T4).
- If improvement in thickness prediction is observed from Step (b), additional effort will be taken to calibrate signal velocity of baseline GPR survey data by integrating the core-based signal velocity.
- If thickness improvement is observed from 900 MHz cart-mounted antenna data, full-width transverse survey using this antenna will be recommended to resume during the CC9 traffic test.

- e) Otherwise, 900 MHz cart-mounted antenna will be dropped from the GPR test plan and only van-mounted system (2 GHz air-coupled and 400 MHz ground-coupled antenna) will be recommended, where full-length longitudinal survey will be conducted at regular offset interval to generate: (i) longitudinal and transverse layer thickness profiles of layer thickness; (ii) monitor possible occurrence of permanent deformation during the traffic test. The details of this recommendation will be documented later, if needed.