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Redesign of the Third-Generation FHWA Pavement Testing Facility

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INTRODUCTION

The Federal Highway Administration's (FHWA's) Pavement Testing Facility (PTF) has been in operation since its creation in 1986.(1) The PTF was originally developed to generate accelerated pavement testing performance data related to design, rehabilitation, and the effect of increased loads, and to support the long-term research efforts of the Strategic Highway Research Program.(2) To that end, the objectives of the first phase of research at the PTF were to establish axle load equivalencies for 11,600; 14,100; and 19,000 lb; compare calculated versus measured pavement response; evaluate the accuracy of the American Association of State Highway and Transportation Officials (AASHTO) design procedure used to initially design the PTF pavement lanes; assess the impact of tire pressures on pavement response; and establish a PTF computer-based information management system.(3,4) The findings from this initial research are well-documented and serve as the foundation for continued studies at the PTF.(4,5,6)

An integral component of the first-generation PTF was the accelerated loading facility (ALF) machine (figure 1). The ALF machine was fabricated specifically for FHWA based on prototypes designed and constructed by the Australian Department of Main Roads, which included a transfer rail system that allowed easy access to the test pavement, an emergency jacking system, and an electrical control and data acquisition system.(1) A second, identical ALF was placed in service during the second-generation PTF era. Additional capabilities of the ALF machines had the following characteristics:

- Machine length and width: 105 ft (32 m) and 13 ft (4.0 m), respectively.
- Tire set: Super single wide based 425/65R22.5.
- Tire pressure: 100 psi (690 kPa).
- Maximum wheel load: 22,500 lb (10,206 kg) with 14,200 lb (6441 kg) typical.
- Operational speed: 11 mph (17.7 km/h).
- Programmable wheel wander: 24 inches (610 mm).
- Isothermal pavement testing: Capable.

The ALFs reached the end of their service lives in 2019. One ALF was transferred to the Australian Road Research Board in October 2022 for a complete rebuild, and the other was scrapped for parts.

With the end of the ALF era at FHWA, the opportunity came to develop the next generation PTF. To ensure the success of the research studies that will eventually be performed in the third-generation PTF, a solid design and construction plan was needed to meet the demands of today and the challenges

Figure 1. Photo. Original ALF machine.

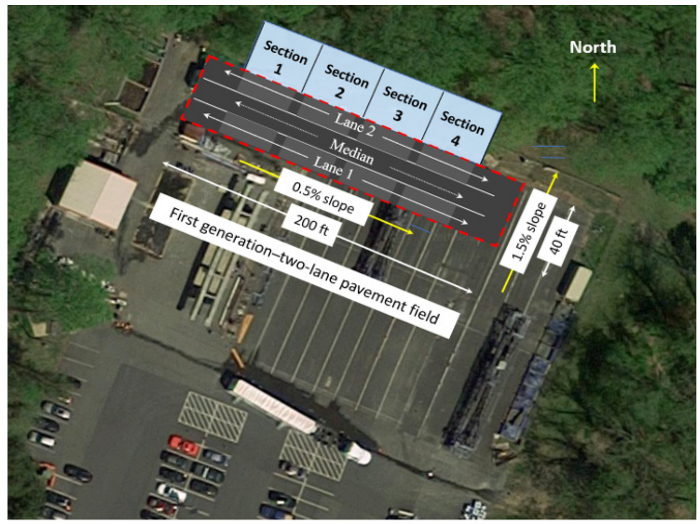
Source: FHWA.

in the decades to come. As a first step, FHWA looked back at the designs for the first-generation (and second-generation) PTFs, learned from those lessons in design and construction, and built on the previous research to further advance the design of the Nation's roadways.

FIRST-GENERATION PTF

The original first-generation PTF began operations in 1986 with the layout of two 200 ft (61.0 m) by 13 ft (3.7 m) lanes, separated by a 13.5 ft (4.1 m) median.[4] Each lane was divided into four longitudinal test sites, with each site (eight total) approximately 32 ft (9.8 m) in length (figure 2). The pavements were constructed on a uniform 3 ft (0.9 m) thick subgrade, classified as an AASHTO A-4(0), with a dense-graded crushed aggregate base course, classified as a Virginia Department of Transportation (VDOT) 21A, and overlain with a hot-mix asphalt concrete (AC) as the wearing course. (See references 5, 7, 8, 9, and 10.) Table 1 summarizes the layer thickness of each section for the original two lanes.

Figure 2. Image. Original, first-generation pavement experiments on the first two-lane pavement field.



Original map: © Google® Maps™. Modified by FHWA (see Acknowledgements section).

Table 1. First-generation pavement layers.

First-Generation PTF Field		Layer Thickness			
		Aggregate Base		AC	
Lane	Section	inch	mm	inch	mm
1	1	4.5	114	5	127
	2	4.8	122	5	127
	3	5.5	140	4.8	122
	4	6.5	165	4.2	107
2	1	11.3	287	7	178
	2	11.2	284	6.8	173
	3	11.8	300	7.3	185
	4	12.8	325	7	178

The initial instrumentation installed during construction included moisture sensors in the subgrade, asphalt strain gauges at the bottom of the asphalt course, and thermocouples throughout the pavement structure.[4,7] In addition to evaluating the structural response of the sections on each lane, the initial work assessed the capabilities and established the operational procedures for the original ALF machine. The work also established the data collection procedures necessary to evaluate pavement response and performance; many protocols that are still practiced today.[5]

Second-Generation PTF

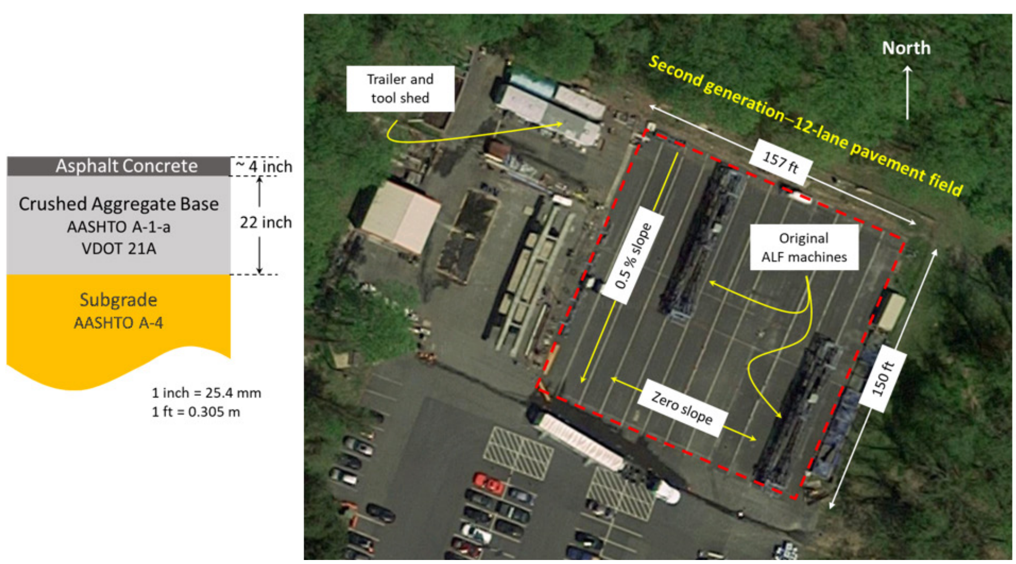
Between 1989 and 1993, the pavement field was redesigned and reconstructed into the current, second-generation, 12-lane configuration.[11] The layout is shown in figure 3. The typical pavement structure was 4 inches (101.6 mm) of AC over 22 inches (558.8 mm) of the crushed granular base material (classified as VDOT 21A) and subgrade.[9] The primary focus during the second-generation PTF was to evaluate the AC wearing course; as such, the unbound materials were solely selected to serve as stiff support for the asphalt and were not representative of conventional pavements.

Shortly after reconstruction of the second-generation PTF, Turner-Fairbank Highway Research Center (TFHRC) received a second ALF machine to enhance the ability of testing pavements. Between 1993 and 2012, the facility was used for the implementation and validation of Superpave™ by testing many different AC mixtures constructed at two thicknesses in combination with different aggregate gradations and binders, including modified binders. (See references 12–16.) During the Superpave era of testing, the methodology of dividing each lane into four test sections to accommodate conducting both fatigue and rutting tests was implemented. (See references 12–16.)

In 2013, the asphalt lanes were milled, the aggregate base surface was reconditioned, and 11 of the 12 lanes were repaved to study fatigue and aging effects of different percentages of reclaimed asphalt pavement (RAP) and recycled asphalt shingle pavement mixtures using both warm- and hot-mix technology.[17–20] In 2016, four lanes were reconstructed to test the effects of AC compaction on pavement performance. During this time, drainage issues were discovered at the pavement field. These lanes were reconstructed by replacing the top 12 inches of the aggregate base course with fresh aggregate materials to facilitate better drainage; however, drainage remained a problem at the site.

In summary, the success of early research at the PTF using the ALF machines, in collaboration with the Asphalt Binder and Mixtures Laboratory (ABML) at TFHRC, has contributed to the development and verification of new asphalt material specifications, designs, and test procedures for flexible pavement technology advancement. In 2018, FHWA initiated the process to upgrade the PTF for a third generation and expand the scope of the program operations and its research objectives by building a new laboratory building, procuring two new pavement test machines (PTMs) with upgraded capabilities, and redesigning the pavement field planned for reconstruction in 2022–2023.

Figure 3. Image. Typical pavement section on the second-generation, 12-lane pavement field.



Original map: © Google® Maps™. Modified by FHWA (see Acknowledgements section).

THIRD-GENERATION PTF RESEARCH OBJECTIVES

Developing the expanded scope of program operations and new research objectives required active collaboration between associated laboratories and research programs at TFHRC, in combination with feedback from external partners in government, academia, and industry. A series of workshops and meetings were therefore held among the internal and external stakeholders to deliberate the future of the PTF. As a result of that process, many research objectives were identified; these objectives were divided into core root and stem objectives. The PTF designers determined that achieving core root research objectives fundamentally depended on the layout and design of the new pavement field, while achieving the stem objectives could be accomplished regardless of the pavement field layout. Figure 4 illustrates the root and stem objectives and highlights the importance of interdisciplinary collaboration and coordination between the laboratories to promote growth of the new research program.

To achieve these multidisciplinary research objectives, the reconstruction incorporated a comprehensive instrumentation program with nearly 300 sensors installed to record the structural pavement response to loading events and to monitor the health of the pavement field with high-speed and low-speed data collection systems.

Core Root Objectives

The identified core root objectives of the third-generation PTF are as follows:

- Evaluate state-of-the-art (SOA) asphalt mix designs and pavement response and performance.
- Conduct comparative analyses of different pavement structures and design methodologies.
- Assess pavement resilience (e.g., time-to-drain evaluations).
- Evaluate the geotechnical aspects of pavements including sustainable construction technologies (inverted pavements).

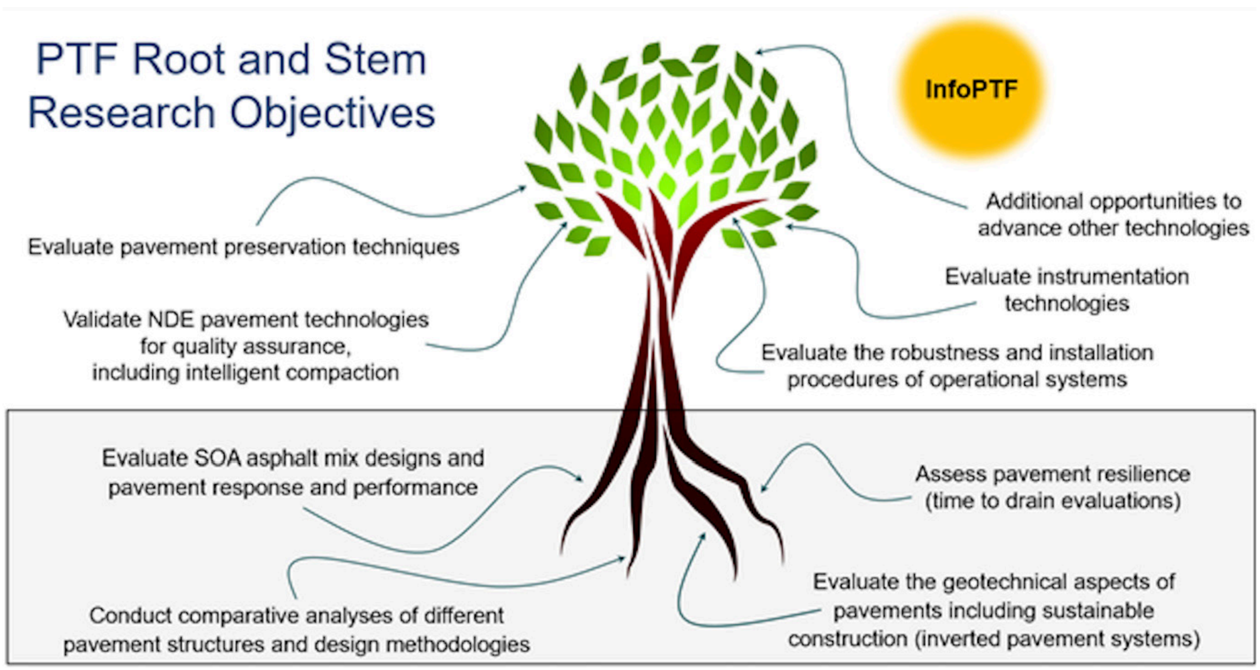
The first two core-root objectives are continuations of the original and second generation PTF, while the last two identified are unique to the new PTF.

Stem Objectives

The identified stem objectives of the third-generation PTF are as follows:

- Evaluate pavement preservation techniques.
- Validate nondestructive evaluation (NDE) pavement technologies for quality assurance.
- Evaluate instrumentation technologies.
- Evaluate the robustness and installation procedures of operational systems.

Figure 4. Illustration. Third-generation PTF root and stem research objectives.



Source: FHWA. Tree illustration: © 2018 GetDrawings.

In addition, the PTF allows for additional opportunities to advance other technologies in the future.

UPGRADE AND REDESIGN OF THE FHWA PTF

The redesign of the third-generation PTF required many upgrades to the infrastructure and pavement field to facilitate the operation of the new PTMs and to meet the design requirements of the new experimental program.

PTF Laboratory Building

FHWA began redesigning the PTF by upgrading the old trailer and auxiliary buildings previously used to support the operations of the first and second-generation pavement field and the old ALF machines. With those facilities at the end of their service life and the needs of the new PTF expanded, FHWA constructed a new PTF laboratory building at TFHRC (figure 5). The exterior dimensions of the building are 26 ft (7.9 m) wide by 70 ft (21.3 m) long. The building includes an office area designed to operate the PTMs and to collect experimental data. The building also has a small electronic shop, a bathroom, a large storage loft, and a high-bay work area for the storage and maintenance of equipment.

PTM

With the phase out of the original ALF machines, FHWA procured new PTMs (figure 6). Fabrication of the new PTMs began in September 2018, and the new PTMs were delivered to TFHRC in October 2020. The following list outlines the basic dimensions and functions of the PTM:

- Machine length and width: 77 ft (23.5 m) and 10 ft (3.0 m), respectively.
- Machine weight: 77,000 lb (35,000 kg).
- Maximum wheel load: 22,500 lb (10,206 kg).
- Tire set: Either dual 11R22.5 or super single 425/65R22.5 tires.
- Variable tire pressure: Typically set at 100 psi (690 kPa).
- Wheel load capabilities: Unidirectional or bidirectional.
- Operational speed: 4.0 mph (6.4 kmh)–7.5 mph (12.1 kmh).
- Wheel wander: 24 inches (610 mm).
- Constant speed test section length: 40 ft (12.2 m).
- Environmental chamber: Heat the pavement surface to 140 °F (60 °C).
- Monitoring: Automated laser-mounted pavement surface profiler system.

Figure 5. Photos. New PTF laboratory building.

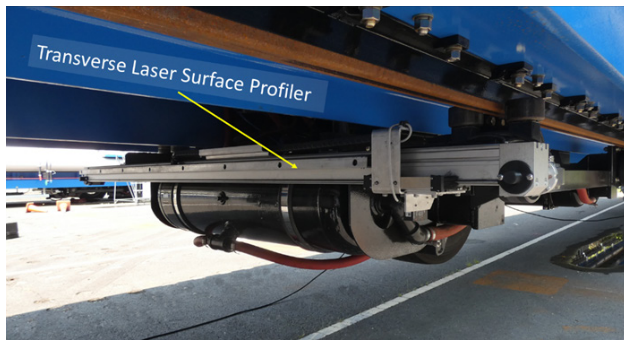
A. Control room side.

B. Work bay side.

All images source: FHWA.

Figure 6. Photos. New PTMs at TFHRC.

A. PTMs on the pavement field.



B. Wheel load carriage.

C. Control room.

All images source: FHWA.

Fundamental Design Requirements and the Pavement Field Layout

The fundamental design requirements of the new pavement field were to improve the surface drainage across the pavement field and rebuild within the existing footprint of the original 12-lane pavement field while expanding the focus of pavement research.

Drainage

Observed drainage issues have long been a problem at the PTF, evidenced by trapped water within the aggregate base layer, oftentimes up to the elevation of the surface pavement layer. Consequently, some premature distresses were observed in a couple of lanes, such as early cracking and rutting and asphalt delamination due to long-term moisture damage in the mix. Through permeability and effective porosity testing of the existing base layer material, classified as an AASHTO A-1-a material, or locally as VDOT 21A, the FHWA Geotechnical Laboratory determined that the time to drain for 50 percent of the water at the PTF (t_{50}) was nearly half a year, given the existing 150 ft (45.7 m) longitudinal length and 0.5 percent cross-slope of the pavement field. [8,9] This finding sheds light on the topic of "free draining" road base materials, which further informed the redesign of the PTF with permeability of the base layers a key factor to analyze in the context of pavement structural performance and distress.

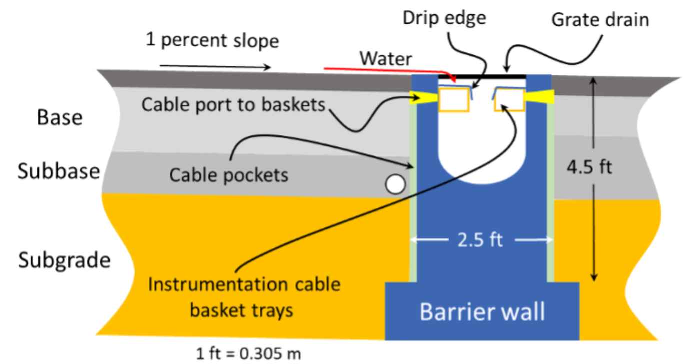
Improvements to surface drainage on the pavement field were achieved in redesign by changing the grade direction from west to east (instead of from north to south), increasing the cross-slope angle from 0.5 to 1.0 percent, and adding several edge drains along the length of the pavement field. The need for edge drains fed into the concept of different pavement pits separated by barrier walls necessary for ultimately achieving the root objectives.

Barrier Walls

Originally, capturing surface water and forming a barrier between pavement pits were the primary functions of barrier walls. These functions quickly expanded to serving as a method for instrumentation cable management and providing a reference elevation across the pavement field for all future experiments. Figure 7 illustrates the design details of the barrier walls that function as edge drains to capture surface water on the 1-percent pavement cross slope, a barrier to form different pavement pits with distinct pavement structures, and a conduit for pavement field instrumentation cables. The edge drains at the top of each barrier wall flow southward at a 2-percent grade into a drainage system at a swale on the south end pavement field.

Design of the barrier walls included stability analyses and checks assuming one side was excavated to a depth of 2.5 ft (0.8 m), and 2.0 ft (0.6 m) of soil surcharge was placed on the unexcavated side. The proximity of a PTM wheel load adjacent to the barrier wall(s) was also checked to verify nonmovement. Future surveys of the third-generation, in-service pavement field will confirm these design requirements.

Figure 7. Illustration. Cross section of barrier wall(s) with details for surface drainage and instrumentation cables.

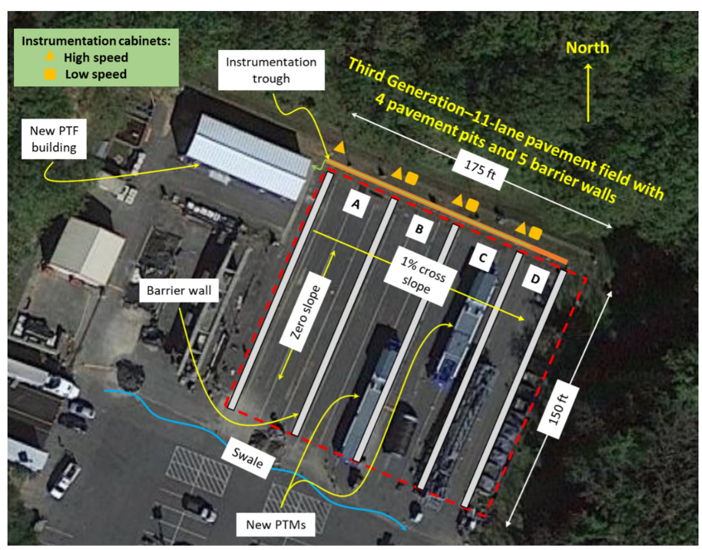


Source: FHWA.

Pavement Layout: Test Pits and Test Lanes

Figure 8 shows the basic layout of the new, third-generation pavement field superimposed over the second-generation pavement field with the four distinct pavement test pits separated by five concrete barrier walls. Pits A, B, and C each have 3 lanes, and pit D has 2 lanes creating a 3-3-3-2 pavement lane layout: a total of 11 lanes. The three lanes in pavement pits A, B, and C, are meant for long-term comparative experiments, while the outside two lanes in pavement pit D are reserved for quicker, short-term experiments. Additional design details of the planned pavement structures for each experimental pit are further discussed later in this technical summary.

Figure 8. Image. Third-generation pavement field layout superimposed over the second-generation pavement field.



Original map: © Google® Maps™. Modified by FHWA (see Acknowledgements section).

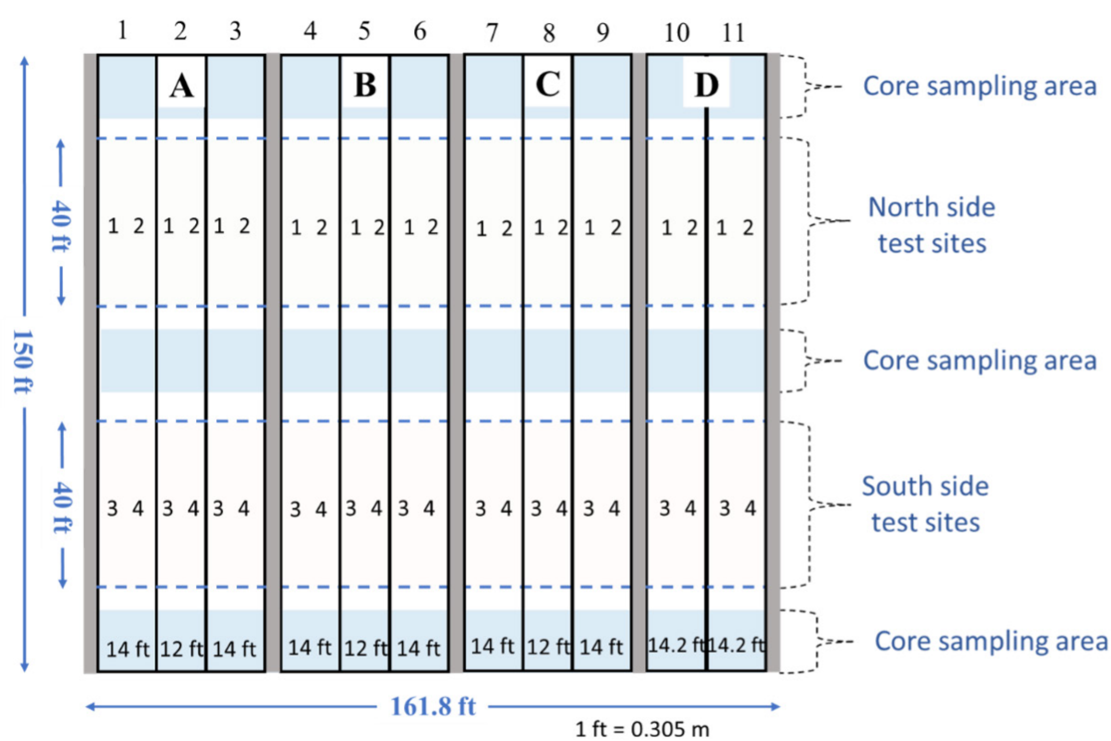
As illustrated in figure 9, the fundamental layout of each lane is like the second-generation pavement field, with each lane divided into four test sites. Each test site is 40 ft (12.2 m) in length to match the constant velocity zone on the new PTMs, with test sites one and two on the northern half and test sites three and four on the southern half of the pavement field. The sketch in figure 9 also shows the upper, middle, and lower regions of the pavement field identified for the collection of laboratory asphalt cores, which can be used to compare the response of the wearing course under accelerated loading and to evaluate the effects of aging.

The initial width of the lanes was set to 13 ft (4.0 m); however, several complications were revealed after superimposing the width of the new PTM on the new pavement field with the concrete barrier walls. Finalizing the lane width in each pavement pit was an iterative process based on satisfying the following conditions:

- Avoid having the 5,600 lb/ft^2 (268 kPa) of pressure from PTM pedestal feet supported directly on the barrier walls.
- Ensure that the distance from the barrier wall to the test sites adjacent to the wall were sufficiently far away to eliminate wall interactions. Finite element method analyses determined that 4 ft (1.2 m) was a sufficient minimum distance to eliminate any boundary effects due to the walls. The final layout provides for 4.4 ft (1.3 m) of distance between the barrier walls and the adjacent test sites (figure 10).
- Maintain the same clear space between interior test sites. The clear space between test sites in the second-generation pavement test lanes was approximately 4 ft (1.2 m); however, for the third generation, the clear space was based on the approximate center-to-center spacing of a standard truck axle length, or 3.8 ft (1.2 m) (figure 10). Slight deviations by 1/8 inch (3.2 mm) were required between some test sites.
- Create a standard layout and standard offset distances to facilitate experimental setups and the movement of the PTMs across the pavement for efficient, repetitive setups.

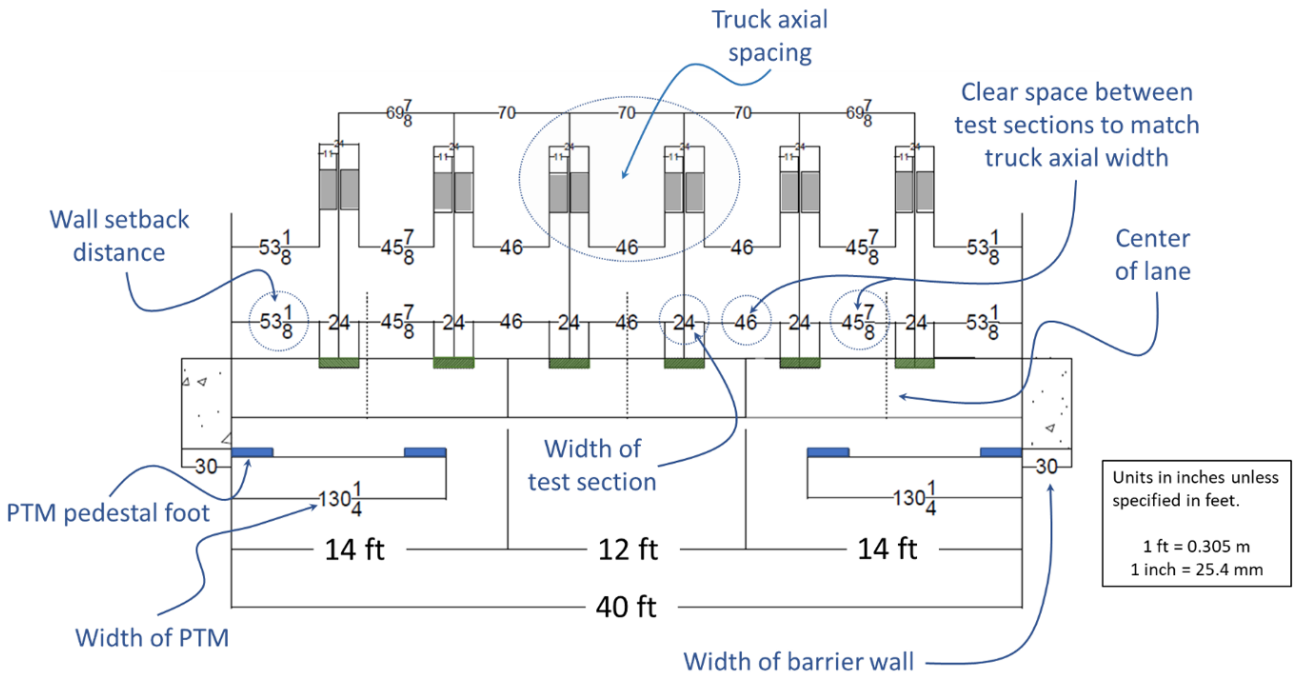
Figure 10 shows the final cross-sectional layout of the test sites across pavement pits A, B, C and D after satisfying the conditions listed previously.

Figure 9. Illustration. Third-generation pavement field layout.

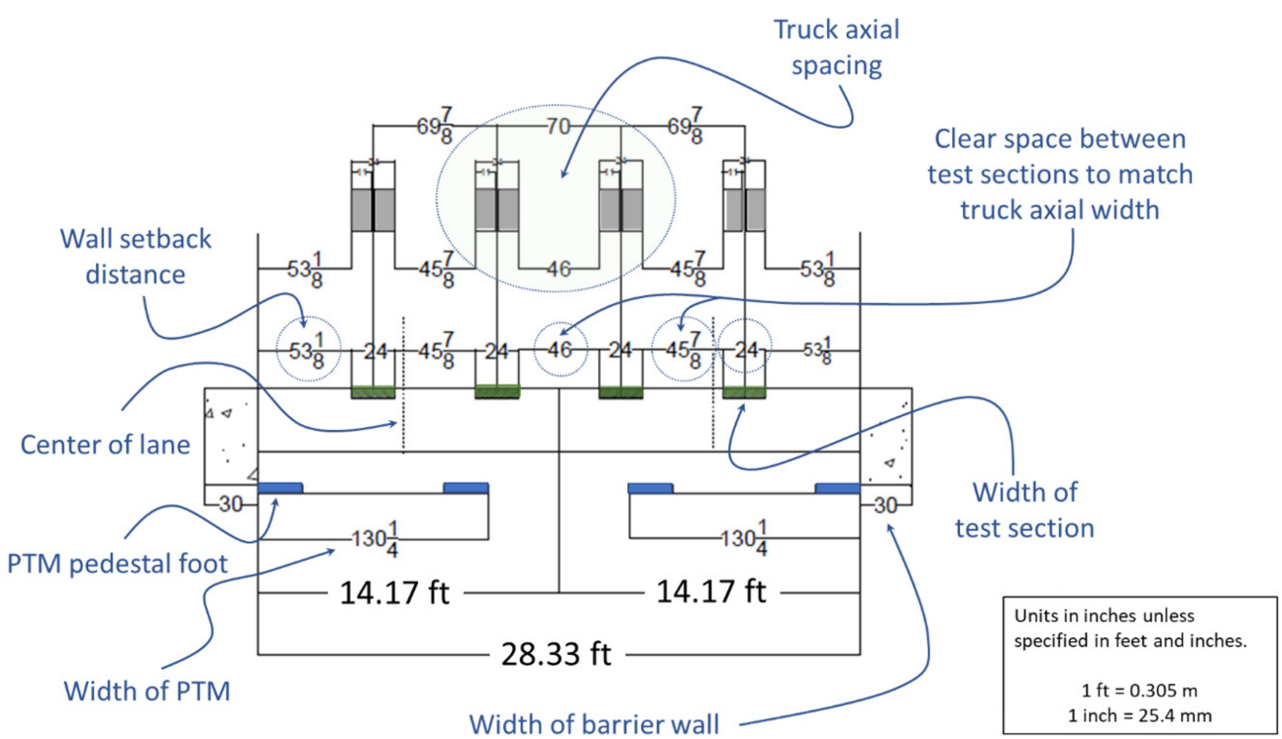


Source: FHWA.

Figure 10. Illustrations. Third-generation PTF lane layout cross sections.



A. Pavement pits A, B, and C.



B. Pavement pit D.

All images source: FHWA.

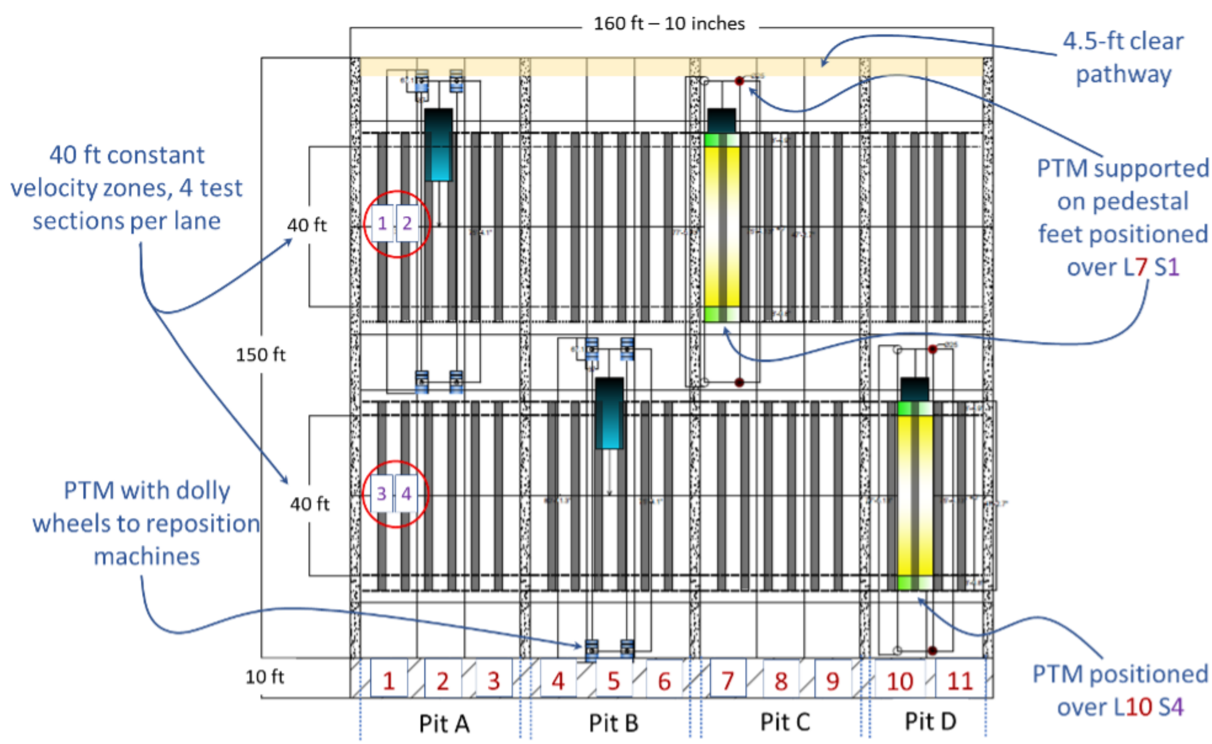
Figure 11 shows the fit of the PTMs positioned over the 40-ft test sections on both the north and south halves of the pavement field. The figure illustrates the conditions of moving the PTMs laterally to place the machines over lane 7 test site 1 (i.e., L7S1) and lane 10 test site 4 (i.e., L10S4). The PTMs can move anywhere within the pavement field within one full work day; however, the typical time for most experimental needs will be about 4 h including setup.

EXPERIMENTAL PLAN

The pavement design for the reconstruction of the PTF pavement test field was based on the major objectives, along with the goals of different research programs and laboratories, including FHWA's ABML, Geotechnical, and NDE laboratories, in addition to the PTF. Materials and layer thicknesses were carefully selected to provide research opportunities to evaluate design methodologies, to test resilience of pavement structures, to observe subsurface drainage, and to model materials and mechanistic behavior of pavement systems, among other program objectives. As part of the variables considered in a pavement design, stiffness and permeability of the unbound layers were defined as critical. Varying the stiffness and permeability of the unbound layers provided an opportunity to include pavements with low, medium, and high structural support, and resilience aspects. The impact of these two important geotechnical characteristics, as well as other potential geotechnical indicators, will further enhance the research opportunities of the facility.

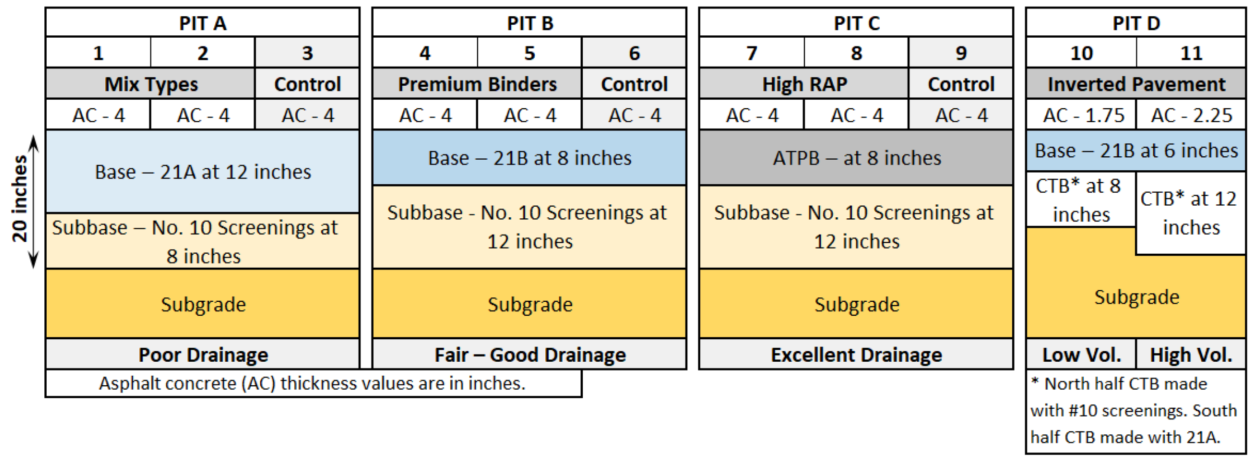
Four pavement pits were designed for the new PTF (figure 12); three for conventional flexible pavements (pits A through C), and one for inverted pavements (pit D). For the three flexible pavement pits, three base materials were selected to provide a reasonable variation of drainage qualities. Two of them are crushed aggregate materials selected to have similar stiffnesses to help isolate the impact of drainage on pavement distress and performance. The third one, in pit C, was selected to be a stiffer, asphalt treated base permeable base (ATPB) material with significantly higher permeability than the base material in pits A and B. The inverted pavement design in pit D was designed with assistance from the aggregate industry through the National Stone, Sand and Gravel Association (NSSGA) based on the standard practice for pavement design in South Africa.[21] The inverted pavement design consists of a crushed aggregate base (the same material used in pit B), over a cement treated base (CTB) and subgrade. The CTB in the north half of pit D was batched with 21A at a targeted cement content of 4 percent and the south half CTB was batched with No. 10 screenings at a targeted cement content of 4 percent. The surface layer in all lanes is AC in various mixture types as shown in figure 12.

Figure 11. Illustration. Positioning of PTMs on the third-generation pavement field.



Source: FHWA.

Figure 12. Illustration. Third-generation pavement test pits.



Source: FHWA.

Pavement Surface Layers

As part of the experimental matrix, each pavement pit received different AC mixes. Pit A was designed to evaluate two types of stone matrix asphalt, and pit B assesses premium binders. Pit C contains 40-percent RAP by weight of mixture. Finally, pit D has a thin 9.5 mm control mix as part of the inverted pavement design.

The far east lane of pavement pits A, B, and C, lanes 3, 6, and 9 were constructed with a 12.5-mm, 20-percent RAP control mix for use as an experimental comparison between the three main pits. FHWA will evaluate the impact of geotechnical characteristics of the base, subbase, and subgrade on pavement performance as part of the root objectives of the PTF. Additionally, drainability (time to drain) will be investigated. The pavement dynamic response to the PTM loading will be measured as moisture content is varied through controlled flooding experiments. Moisture and stiffness measured in the field and laboratory will be correlated to pavement performance measures, such as cracking and rutting.

Base and Subbase Layers

For continuity and comparison between the second- and third-generation PTFs, one pit (pit A) was designed with the existing base layer material, classified as an AASHTO A-1-a, or locally as VDOT 21A.[8,9] This material has relatively low permeability, on the order of 1 ft per day. For pit B, a coarser crushed aggregate with lower fines content, classified as a VDOT 21B, was selected to serve as the medium permeability test pit, with permeability targeted to be an order of magnitude higher than the base material in pit A.[9] The base material selected for pit C was an ATPB, which provides the highest relative permeability. The same subbase material, classified as No.10 screenings, was selected for pits A–C.[22] The No.10 screenings are a quarry byproduct shown to have adequate engineering properties for pavement applications; cement treatment of the No.10 screenings is also planned for the inverted pavement system in the north half of pit D.[23]

FHWA performed preliminary work to characterize permeability and resilient modulus on each planned base and subbase material. The resilient modulus results served as inputs for a 1993 AASHTO structural design of the pavements in each pit.[24] The objective of the structural design was to determine appropriate layer thicknesses that would allow for meaningful comparisons between the different pavement pits in the future. Different thicknesses for the base and the subbase will allow for testing the sensitivity of different pavement design methodologies while advancing pavement design. A geosynthetic separator was placed between the subbase and subgrade across the entire pavement field to mitigate base contamination and to facilitate reconstruction projects; however, the geosynthetic separator's impact is not directly evaluated in the current structural design.

Between the two pits with a crushed aggregate base (pits A and B), the preliminary design suggests that the equivalent single axle load (ESAL) in pit B would be about three times greater than in pit A. The use of a subbase in the third-generation PTF is a deviation from the existing, second-generation pavement cross section; this addition doubled the target ESALs in pavement pit A.

As a result of the preliminary structural design and ESAL analysis, the base material in pit A (VDOT 21A) was designed with a cross section of 12 inches (304.8 mm) over 8 inches (203.2 mm) of the No. 10 screenings.[9, 22] Pit B was designed with 8 inches of VDOT 21B over

12 inches (304.8 mm) of No. 10 screenings. For pit C with the ATPB, the design approach was different and simply employed the same cross section used for the intermediate condition (i.e., pit B). Pit C is therefore designed with 8 inches of ATPB over 12 inches (304.8 mm) of No.10 screenings, approximately 15 and 5 times higher as compared to pits A and B, respectively. Combined with pit D, which will have a total of four inverted pavement cross sections, the structural design of the new PTF field will include pavement cross sections that will have four different structural capacities and traffic support conditions, and four different levels of permeability (figure 11). With this matrix of pavement conditions, the PTF program will be able to address major goals and include most disciplines related to pavement engineering.

Subgrade

The subgrade material at the site remains largely unchanged throughout all generations of the PTF, except for blending to ensure uniformity and compacting the material into place. The subgrade is a nonplastic, reddish brown silt, known locally as saprolite, and was initially classified as an AASHTO A-4(0) material.[5, 8]

Pavement Resilience

As a root objective of the third-generation PTF, FHWA will evaluate the resilience of the pavement field under flooded conditions in the future. The south half of the pavement field was therefore designed to be inundated with water; the different permeabilities of the base layers will play a critical role in the response. Combined with enhanced instrumentation, controlled flooding will allow the evaluation of pavement structural response as a function of moisture variation, including extreme conditions of full saturation and the t_{50} time-to-drain estimates as previously mentioned.

INSTRUMENTATION PROGRAM OVERVIEW

In the first two PTF generations, measurements of pavement performance and structural nondestructive testing have been the main components of data outcome. Measurements of internal responses have not been consistently used in the past experiments. Therefore, a vital component of the new, third-generation PTF is the array of instrumentation that is permanently installed. The key objectives of the instrumentation program include the following:

- Monitor the health of the pavement field integrated with weather data.
- Collect data to achieve the research objectives for the individual experiments.
- Evaluate the geotechnical aspects of pavements and their impact on the mechanistic behavior of pavements.
- Store and manage the information for widespread use.

In addition to the permanent instrumentation, experiment-specific instrumentation may be installed later so the pavement field and data acquisition systems can accommodate future needs.

Core Sensors and Locations

In the instrumentation program, FHWA selected the measurement devices to provide the following information:

- Longitudinal and transverse strain within the surface layer, either collected at the bottom or the top of the wearing course.
- Vertical compressive deformation of unbound layers.
- Permanent deformation of the surface (total deformation of the pavement) and of the top of the base (total deformation of unbound layers).
- Vertical compressive stress at the interface between layers.
- Lateral compressive stress at the wall that separates the pavement pits.
- Moisture content collected at the interface between pavement structural layers.
- Temperature data collected throughout the wearing course (surface layer temperature profile) and at the pavement foundation layers.

Stress, strain, and deformation sensors collect data during loading operations at high frequency (i.e., 250 Hz) to capture the entire load pulse. Moisture and temperature sensors collect data continuously throughout the pavement test field at low frequency (e.g., hourly). Along with their use to monitor the health of the pavement field, the sensors are also used to evaluate the conditions for accelerated load testing and alert when abnormal conditions are occurring to avoid premature damage of the pavement.

Considering the resources required, the instrumentation program primarily focused on two test sites within each pavement lane. A sensor line connecting an array of instrumentation was installed in test site 1 (S1) within the north half of the pavement field and in test site 4 (S4) in the south half of the pavement field. The response is anticipated to be equal in the other two test sites, (e.g., sites 2 and 3) within each lane. In total, there are 22 sensor lines across the pavement field. Each of the 22 sensor lines across the pavement field are identical and comprises the following elements:

- One vertical pressure cell (VPC) at the subgrade/subbase interface.
- One VPC at the subbase/base interface.
- One VPC at the base/surface layer interface.
- One soil compression gauge at the base/surface layer interface.
- Two sets of longitudinal and transverse asphalt strain gauges on the bottom of the wearing surface (installed during construction before paving).

Figure 13 shows the locations for the instrumentation in each 40-foot sensor line. The top part of the illustration is a plan view of the sensor line, and the bottom part is a cross-sectional view that shows the depths of the sensors within the pavement structure along each sensor line. The purpose of the moisture sensors is to monitor the entire pavement field; 105 moisture sensors were installed within and beyond the sensor lines between subgrade, subbase, base, and asphalt layers. The count for all the planned instrumentation is provided in table 2. In total, over 289 sensors will be permanently installed during construction of the third-generation PTF. Additional strain gauges will be installed on the top asphalt layer before running any accelerated tests, and other experiment-specific sensors can be included as needed.

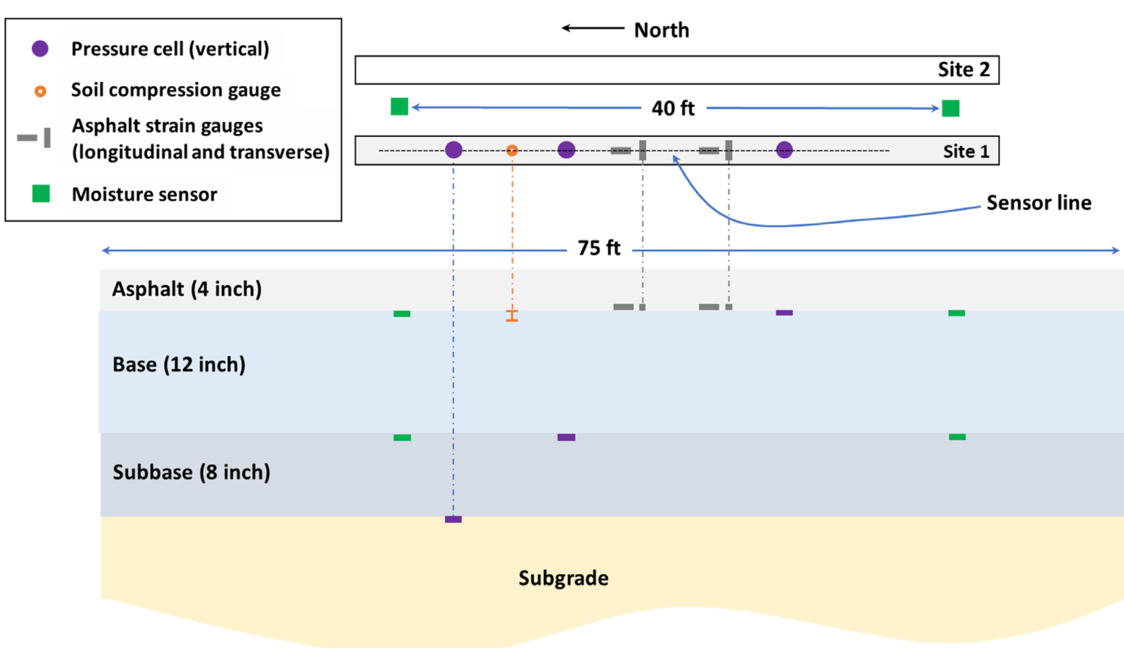
Table 2. Planned instrumentation at the third-generation PTF.

Core Instrumentation			Totals
Moisture sensors			105
Dynamic vertical pressure cells			66
Dynamic lateral pressure cells			8
Soil compression gauges			22
Asphalt strain gauges	Top	Longitudinal	44
		Transverse	44
	Bottom	Longitudinal	44
		Transverse	44

Data Acquisition

The data acquisition systems were designed to maximize usage of the PTMs and provide frequent intervals of response measurements. Two data collection systems were developed, a high-speed (HS) system to measure the pavement dynamic response from the PTMs loading, and a low-speed (LS) system to monitor the health of the pavement field. As shown in figure 8, there are 4 HS and

Figure 13. Illustration. Plan and cross section view of test site sensor line.



Source: FHWA.

3 LS systems stationed at the north end of the pavement field with an instrumentation trough across the north side of the pavement field for hardwired connections directly inside the PTF lab building. The HS data collection will be synchronized with the schedule and position of the PTMs and will collect data at a minimum rate of 250 Hz. The HS and LS systems will each have a dedicated data-collection computer. The PTMs are scheduled to run day and night with periodic intervals for measurements of dynamic response depending on the experiment. LS data collection will be a continuous operation because LS data collection is designed to monitor the health of the pavement field. Data from moisture and temperature probes will be monitored continuously; trigger alarms will also be coded in the software to flag any dramatic changes in the pavement field to alert the PTF operations staff.

Logistical Details

With any instrumentation program, the following details create a dynamic, complex environment that require close attention for smooth operation:

- Ensuring the total diameter of the planned instrumentation cables fit in the cable pockets within the barrier walls.
- Calculating the necessary cable lengths from the instrumented site to the data-collection cabinets.
- Evaluating the impact of the high-power voltage required for the PTMs and any electrical instrumentation interference that could occur.
- Calibrating sensors and confirming operation and required cable lengths.
- Developing a system for sensor nomenclature and labeling.
- Setting up and programming the data acquisition systems.
- Designing the instrumentation cabinet layout.
- Coordinating with the construction contractor to ensure success for all parties.
- Developing roles and responsibilities for the installation team so the process runs smoothly during reconstruction.
- Being prepared for unforeseen conditions during construction (e.g., field splices may be needed in the event of construction damage to instrumentation cable).

NEXT STEPS AND FUTURE WORK

The next step for the third-generation PTF is to finalize the experimental plan, catalog all the as-built construction information, test and validate baseline instrumentation reading, take in-situ measurements for quality assurance, and collect samples to characterize the as-built pavement materials in the laboratory.

Construction

Construction of the new pavement field largely followed the Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-14).[25] Exceptions to FP-14 include the tolerances of the layer thicknesses, which for this project required tighter tolerances of 1/4 inch per a 10-ft straight edge, and the use of VDOT specifications for the CTB material in pavement pit D.[9]

To ensure the pavement materials meet the requirements for the experimental matrix in terms of permeability and stiffness for each pavement pit, the Government furnished many of the materials for construction. In addition, some of the specialized experimental asphalt mixes were also Government-furnished to reduce contractor risk. The Government-furnished materials include specialized asphalt mixes in lanes 5, 7, and 8, all subbase and aggregate bases, and the portland cement-treated base materials for the inverted pavement section in pavement pit D.

To improve the quality assurance and uniformity of the compacted layers, the construction included the use of intelligent compaction on all the pavement layers with incentivized payments for roller coverage and stiffness uniformity included in the contract. Additionally, during the installation of the instrumentation (while the construction contractor was not working in that pavement pit), a variety of in-situ tests (e.g., nuclear density, falling weight deflectometer, dynamic cone penetration, rolling density meter) were conducted to further characterize the condition of the as-built pavement layers.

Future Work and Operational Procedures

To support these expanded PTF operations, the PTF program has formed collaborative partnerships between the ABML, Geotechnical, and NDE research programs to achieve many of the objectives, with research expected to advance the next generation of pavement design and analysis. With many different data sources and teams involved, a foreseeable challenge is the ability to systematically catalog, store, manage, and retrieve all the information for continued long-term use by various parties. Therefore, an information management system (i.e., InfoPTF) is under development with standard protocols that provide a collective forum for successful application of the datasets collected, including the integration and fusion of all the data collected from the PTF.

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The original photos in figure 2, figure 3, and figure 8 are the copyright property of Google® Earth™ and can be accessed from https://www.google.com/earth.[26] Map data came from the USGS National Geologic Map Database and can be accessed from https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html.[27] FHWA developed the map overlays for figure 2, figure 3, and figure 8 to add labels and arrows. The overlay for figure 2 shows the original, first-generation pavement experiments on the first two-lane pavement field. The overlay for figure 3 shows the typical pavement section on the second-generation, 12-lane pavement field. The overlay for figure 8 shows the third-generation pavement field layout superimposed over the second-generation pavement field.

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