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Enhanced Capabilities of the Illinois Accelerated Pavement Tester

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16. Abstract

After being in service for nearly 20 years, the Illinois Accelerated Pavement Tester (I-APT) was upgraded to provide enhanced capabilities for accelerated pavement testing. In addition to a new control system, the improvement included a newly designed load carriage, which allows for testing with a tandem half-axle, axle yaw, and shear loading (breaking and accelerating). The new I-APT design could be fitted with various tire configurations (e.g., single, dual, wide-base, and aircraft). In addition, a tandem axle can be used that has the ability to vary axle spacing between 37 and 68 in. and wander tracking up to 18 in. Loading at a yaw angle of up to 6 degrees will now be possible, simulating lateral force, along shear force simulating skidding on pavement, which requires torque variations. Other improvements include the following: i) replacing the original electrically activated winch with a hydraulic power system, which will minimize electrical noise interferences with sensor signals; ii) advanced computing system file management using LabView codes; and iii) a new control trailer to operate the device.

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Members of the Technical Review Panel (TRP) were the following:

- John Senger, TRP Chair, Illinois Department of Transportation
- Megan Swanson, Illinois Department of Transportation
- LaDonna Rowden, Illinois Department of Transportation

The authors would like to acknowledge Barry Dempsey's visionary and original design of the I-APT project.

EXECUTIVE SUMMARY

The Illinois Accelerated Pavement Tester (I-APT), previously known as the Accelerated Transportation Loading Assembly System (ATLAS), underwent repairs and significant upgrades since its initial acquisition in 2002. This system, crucial for numerous accelerated pavement testing (APT) projects, features a carriage moving along a pavement test section beneath a steel frame. The 85 ft long I-APT is mounted on crawler tracks for easy relocation between test sections and offers ample clearance for testing. Complementing the main system, two trailers adjacent to I-APT provide essential power and control.

I-APT's carriage can utilize various axle and tire configurations to apply loads up to 80 kips in testing diverse pavement systems. Over its 20 years of operation, I-APT has seen several repairs, including the replacement of the winch's steel cable, upgrades to the swing arms transferring vertical axle loads, and refurbishments to its servo-hydraulic system. In 2008, a temperature control system was added, enabling tests at specific temperatures, irrespective of external conditions. Addressing challenges in the original design, such as loading precision, electrical noise affecting sensor signals, aging components, and an outdated control system, I-APT underwent a comprehensive upgrade in 2023. This modernization caters to the evolving demands of pavement engineering, particularly focusing on sustainable preservation. The enhancements include:

- A new, versatile tandem axle configuration, offering a choice of single-axle or tandem-axle testing. This configuration allows adjustable axle spacing and the option of using one or two axles during unidirectional or bidirectional trafficking.
- Axle yaw feature, which rotates wheel axles up to 6 degrees relative to the direction of travel. This function applies side slip shear force to the pavement during load trafficking, controlled by normal load or optional side force feedback, and is adjustable in both directions.
- Enhanced shear capability for simulating braking and acceleration forces, especially pertinent due to the high torque of modern electric vehicles. This feature facilitates simultaneous vertical and shear loading, powered by a dedicated hydraulic system.

Other improvements include the conversion of the winch system from electric to hydraulic for noise-free sensor measurements, a reduction in the vertical load range to 35 kips with enhanced loading resolution, and the introduction of a new carriage wheel design with two soft wheels at each corner, ensuring constant rail contact even at smaller loads. A new control trailer houses the state-of-the-art control system.

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CHAPTER 1: INTRODUCTION

PURPOSE

This report documents the enhanced capabilities of the Illinois Accelerated Pavement Tester (I-APT), previously known as the Accelerated Transportation Loading Assembly System (ATLAS), highlighting the recent upgrades. The new testing capabilities allow for innovative loading methods that surpass the standard practices of existing accelerated pavement testing (APT) systems.

SCOPE

Full-Scale Accelerated Pavement Testing

The need for quicker, more practical evaluation methods for pavement systems under conditions that closely simulate real-world use led to the development of APT. Bridging the gap between small-scale laboratory simulations and real-life pavement monitoring, full-scale APT has been a crucial tool. Though used in a basic form since the early 1900s, the last four decades have seen significant advancements and global proliferation of APT. Generally, APT is defined as a controlled application of a realistic wheel loading to a pavement system to simulate long-term, in-service loading conditions (Choubane et al., 2019). Evaluating pavement response and performance under accelerated, controlled conditions offers significant benefits, such as predicting pavement performance, reducing costs, and testing new technologies and pavement systems.

I-APT Research

I-APT, housed at the Illinois Center for Transportation (ICT) in Rantoul, Illinois, is a unique, large-scale device for testing pavement under simulated heavy vehicle loads. The State of Illinois and the Illinois Department of Transportation (IDOT) provided $1.5 million toward the development and construction of I-APT. Operational since June 2002 (Kohler & Roesler, 2006), it has been instrumental in numerous research projects. A partial list of these projects is provided in Table 1. It has been used for developing Illinois flexible and rigid mechanistic pavement design, pavement interface materials, reflective cracking, new mixes in concrete and asphalt, fiber-reinforced ultrathin overlays, quarry by-product bases, local aggregate in stone-matrix asphalt (SMA), and the development of tack coat standards, to name a few. Three projects received non-IDOT funding: Asphalt Geogrid, funded by Tensar International; Asphalt Reflective Cracking, funded by the National Science Foundation; and Concrete Short Slabs, funded by TCPavements. I-APT has been repositioned approximately 50 times for testing over 100 different pavement test sections. The insights from these projects have not only assisted IDOT in developing specifications, significantly advancing the global field of pavement engineering, but have also contributed to academic publications and conferences.

Table 1. Partial List of I-APT Projects 2002–2019

Pavement Family	Research Short Name	Section Construction Year	Report Title
Concrete	CRCP	2001	*Accelerated Pavement Testing of Extended Life Continuously Reinforced Concrete Pavement Sections* (FHWA-IL-UI-289)
Asphalt	Extended Life	2003	*Extended Life of Hot Mix Asphalt Pavement (ELHMAP) Test Sections at ATREL* (FHWA-ICT-08-017)
Asphalt	New Tires	2003	*Evaluation of Pavement Damage Due to New Tire Design* (FHWA-ICT-09-048)
Asphalt	Geogrid	2005	*Special Study to Quantify Geogrid Effectiveness in a Low-Volume Flexible Pavement* (Several technical papers)
Asphalt	Tack Coat	2005	*Tack Coat Optimization for HMA Overlays: Accelerated Pavement Test Report* (FHWA-ICT-09-035)
Asphalt	Reflective Cracking	2006	*Cost-Effectiveness and Performance of Overlay Systems in Illinois Volume 1: Effectiveness Assessment of HMA Overlay Interlayer Systems Used to Retard Reflective Cracking* (FHWA-ICT-09-044)
Concrete	Short Slabs	2007	*Performance of Concrete Pavements with Optimized Slab Geometry* (ICT-09-053)
Asphalt	Moisture Susceptibility	2009	*Effects of Various Asphalt Binder Additives/Modifiers on Moisture-Susceptible Asphaltic Mixtures* (FHWA-ICT-14-004)
Aggregates	Subgrade/Subbase	2010	*Field Performance Evaluations of Illinois Aggregates for Subgrade Replacement and Subbase—Phase II* (FHWA-ICT-12-021)
Asphalt	Fine-Graded HMA	2011	*Designing, Producing, and Constructing Fine-Graded Hot Mix Asphalt on Illinois Roadways* (FHWA-ICT-15-009)
Aggregates	Large Aggregates	2014	*Evaluation of Aggregate Subgrade Materials Used as Pavement Subgrade/Granular Subbase* (FHWA-ICT-15-013)
Aggregates	By-products	2017	*Field Performance Evaluation of Sustainable Aggregate By-product Applications* (FHWA-ICT-18-019)

At the time of this report, the last I-APT research project was completed in April 2018. Subsequently, a decision was made to upgrade I-APT to meet the evolving needs of pavement engineering, focusing on enhancing its capabilities and control system. The condition of I-APT, its upgrading process, and its new testing capabilities are presented in this report.

CHAPTER 2: I-APT OPERATIONAL CONDITIONS PRIOR TO THE UPGRADE

ORIGINAL DESIGN AND SPECIFICATIONS

In 2001, the University of Illinois transportation faculty decided to build a loading system to perform full-scale testing using truck, aircraft, and railcar loadings. Barry Dempsey developed a set of specifications for the original APT system that would later become I-APT.

Applied Research Associates was awarded the contract and, in 2002, delivered a pavement engineering research tool designed to apply a rolling load of up to 80 kips to a pavement surface. This could be achieved through truck or aircraft tires or a standard railroad axle, over a traverse distance of 85 ft at a top speed of 10 mi/hr. I-APT was capable of performing 6,000 repetitions per day.

Main Components

Its design centered around a steel frame consisting of two parallel welded steel box beams extending beyond the length of the test section. The two beams were connected by a steel support structure at each end and a solid steel plate spanning their entire lengths. The wheel load was applied by a hydraulic load system mounted on a carriage, which traversed the 85 ft length. The total height of the structure is 12 ft, with the base of the main structure approximately 6 ft above ground level. This design allows for falling weight deflectometer (FWD) tests on the pavement section without moving I-APT. The main dimensions and parts are shown in Figure 1, including box beams, two crawler track systems, and a load carriage.

Complementing the main system, as shown in Figure 2, are two adjacent trailers. One is the control trailer, housing the control panel where the operator manages the computer during equipment operation. The other is the mechanical trailer, containing elements such as an electrical transformer, hydraulic pump, and air compressor. An electrical connection runs from the grid to the mechanical trailer, and hydraulic hoses connect the mechanical trailer to the system.

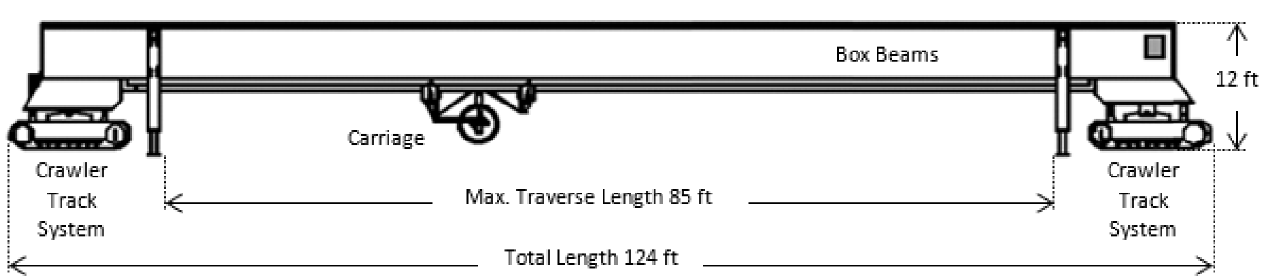


Figure 1. Illustration. I-APT main dimensions and parts.

Figure 2. Photo. Control trailer and mechanical trailer.

I-APT can be positioned using a propulsion system built around two pairs of crawler tracks. The hydraulically driven tracks are powered by a diesel engine mounted at one end of the I-APT (Figure 3). Each pair of tracks is mounted under one end of the main structure in such a way that it can rotate 90 degrees around the vertical axis when the structure is raised on four hydraulic lift legs. This design enables I-APT to move longitudinally, transversely, or change direction. The diesel engine for the propulsion system is operated and monitored from a console mounted on one of the lift legs. A hand-held control box, connected by a cable to I-APT, enables control of the hydraulic propulsion functions whenever the system needs to be repositioned. The pavement loading system and the propulsion system for repositioning I-APT on the test site operate independently.

Figure 3. Photo. Diesel engine that operates the crawler track system.

The loading wheel is attached to the carriage, which is propelled along the length of the loading path by a cable and a winch. The load carriage consists of three independent steel weldments. The first, called the main frame, simply traverses the test section. The wander frame is attached to the main frame with transverse linear bearings. It moves laterally with respect to the main frame to provide wheel wander and serves as an attachment point for the fixed ends of the hydraulic cylinders that apply the load. The swing arms move vertically with respect to the wander frame as necessary to apply or remove wheel loading to the pavement.

Loading Carriage

The loading carriage is shown in Figure 4, which travels across a pavement test section. Figure 5 shows two more detailed views, illustrating the previously described features:

- **Main Frame**: Supports the hydraulic equipment, the wander frame assembly, load wheels, and return wheels.
- **Wander Frame**: Supports the cylinders, swing arm, and wheel assembly. It slides on two hardened steel rods, which permits lateral positioning of plus or minus 18 in.
- **Swing Arm**: Suspended from the wander frame, it supports the wheel assembly.

Figure 4. Photo. Loading carriage of I-APT.

Figure 5. Photo. Detail view of the loading carriage.

When loading was applied to a wheel, the carriage is laterally restrained by flanged steel wheels running on a pair of steel reaction rails (Figure 6). One rail is attached to the bottom of each of the main box beams. For unloaded traversing, four return wheels rolling on the extended lower flanges of the main beams support the load of the carriage, with horizontal guidance provided by the flanged wheels (Figure 7).

Figure 6. Photo. I-APT reaction rail.

Figure 7. Photo. Return wheel running on flange.

The carriage is propelled along the rails by a winch mounted at one end of I-APT, through two steel cables that attach to both sides of the load carriage, one of them by way of a static sheave at the opposite end of I-APT.

The winch is an electrically powered cable drum used to propel the carriage. The winch is shown in Figure 8. It features a 150 HP 460 Volt 3 phase vector drive motor with encoder feedback, and a gear reduction connecting the motor to the cable drum.

Figure 8. Photo. Winch and steel cable.

PAST REPAIRS AND IMPROVEMENTS

Steel Cable Replacement

The steel cable exerted a large force pulling the carriage. Wear and tear from these large forces required replacing the cable every two to three years.

Swing Arms Upgrades

In 2003, the swing arms were replaced with larger, 5 × 5 in. steel members. Since then, these swing arms, connected by 3 × 5 in. steel members, have extended over 52 in. from the pivot point on the carriage to the wheel axle. These upgrades were implemented to prevent uneven loading on both sides of the wheel axle.

Temperature Control and Heaters

An important upgrade to I-APT was the addition of a temperature control system in 2008. The insulated environmental system, shown in Figures 9 and 10, facilitates temperature regulation inside the test area using A/C or environmental heaters. The system was comprised of panels forming a portable structure, deployable as required by the research.

Figure 9. Photo. Temperature control panels as viewed from outside.

Figure 10. Photo. Inside the temperature control enclosure.

NON-OPERATIONAL I-APT

By 2019, I-APT required significant repairs and upgrades. In addition, the I-APT control system, outdated and not maintainable by ICT personnel, had remained unchanged despite two decades of advancements in software and control systems. Testing could not continue without updating the control system to meet current software and hardware requirements. This presented an opportunity to enhance ICT's capabilities in accelerated pavement testing by transforming I-APT into an advanced testing and control system.

Software

Operating System

I-APT was controlled using a computer that operated on Windows 2000, released in February 2000 and supported only until July 2010. With the rapid pace of technology advancements, it was not feasible to upgrade the operating system of the I-APT computer to Windows 8 in 2012, nor to Windows 10 in 2015. While I-APT did not require connection to external networks to function, the lack of support from system updates was evident. The outdated operating system was manageable for a finite period; however, the limitations of an unsupported operating system increasingly posed challenges.

Control Software

The control software allowed the operator to specify all testing parameters as well as initiate, pause/restart, and stop pavement testing. Once a test had started, the operator's console provided a real-time display of operating parameters and the overall status of the system. Figure 11 shows screens from the control software: a) main screen, b) test configuration screen, c) run time screen, and d) manual operation screen.

Figure 11. Illustration. Examples of I-APT control software in Windows 2000 (ICT, 2005).

The control software could neither be updated to newer operating systems nor improved without involving the manufacturer. It also lacked some functions in data file management and the ability to automatically shut down in case of emergencies. To address safety issues and safeguard the integrity of I-APT, the installation of a modern control system was necessary.

Condition of Specific Components

Carriage

The existing return wheel mounts on the carriage required a redesign to maintain rail contact at smaller loads. This issue had created uncertainty in the accuracy of the load applied along the track, stemming from the wide range of original load designs and the reliance on hydraulic oil pressure for load sensing. The ICT team determined that 35,000 lb of downward force was enough for most of the testing that historically had been conducted with I-APT, and this load level was set for future testing. The reduced load capacity would be sufficient for the dual in-line truck wheels but would require a new carriage fitted with load cells instead of pressure transducers. The load cells would significantly improve load measurement accuracy, reducing uncertainty from an estimated 569 lb to 80 lb.

Winch

The operation of the winch created electrical noise that interfered with some sensor signals. A Baldor vector drive was installed originally to control the operation of the winch and, therefore, the movement and position of the loading carriage. This vector drive emits a strong electromagnetic field when operating, which can interfere with low-voltage systems. Sensors used to monitor pavements are typically low-voltage systems relying on less than 10 volts of signal strength to provide feedback responses. Due to this low voltage, the electrical interference or noise from the vector drive can mask the change in voltage of the sensors, and, thus, valid data cannot be obtained from test measurement sensors. Efforts were made in the past to install power filters in-line with the vector drive; however, this did not resolve the issues.

Control Trailer

The control trailer, still using Windows 2000, required replacement. A modern version with an updated Windows operating system and larger windows for observing testing would enable a full view of I-APT during operation. Equipment needing replacement included the control computer, cabling, and the uninterruptible power supply.

Crawler Power

The crawler power to the I-APT system may have been originally under-designed. Its operation was slow and challenging when moving the system, possibly due to efficiency loss over time. Although the crawler track system's power was independent from the normal testing operations, its infrequent use when relocating I-APT to different test sections indicated that efficiency upgrades were essential for more effective movement to desired testbeds.

CHAPTER 3: NEW CAPABILITIES

OVERVIEW OF THE UPGRADES

Objective

The upgrades and repairs implemented on I-APT, formerly known as the Accelerated Transportation Loading Assembly System (ATLAS), were made to ensure this important ICT asset continues to provide valuable insight into pavement responses to load. These enhancements modernized the two-decade-old machine, offering cutting-edge capabilities, reducing test time and maintenance, and improving efficiency. Simplifying training for various researchers to operate the system was also a key goal. Above all, increased safety was paramount in the decision to upgrade I-APT.

A modernized I-APT reinforces ICT´s position as a world-class transportation research facility and a premier destination for all material and pavement testing. This aligns with the core missions of both IDOT and ICT.

About the Upgrades

Past Issues Resolved

As mentioned, there were a series of operational difficulties that prevented I-APT from running. Key issues addressed included reducing electric noise from the winch to minimize interference with experimental instruments and updating the control program to operate on a modern system. Additional improvements involved replacing the control trailer, upgrading the hydraulic loading system, maintaining rail contact (especially at small load levels), and enhancing crawler power for more efficient movement of I-APT to desired testbeds. All of these issues have been resolved.

The main original capabilities were retained, including displacement and load control, variable load, adjustable trafficking speed, wheel wander, and the possibility of using multiple wheel configurations (dual tire assembly, wide-base, and aircraft). In addition, a rail wheel bogey can also be installed.

Contractor

Advanced Innovation Systems (AIS) was selected as the upgrade service provider. The lead technical engineer for AIS had been a lead project engineer during the initial design and construction of the I-APT system more than 20 years earlier.

Practical Difficulties During the Upgrade Work

The upgrade of I-APT began in March 2021, a year into the COVID-19 pandemic. This timing resulted in supply backlogs as well as delayed shipments and services. The lack of availability of certain components required the design to be altered and additional time was required to source, design, and engineer replacement components into the I-APT upgrades.

MAJOR NEW CAPABILITIES

The new capabilities that make I-APT a world leader in accelerated pavement testing are associated with the newly enhanced load carriage (Figure 12). The enhanced carriage accommodates tandem axle configuration, axle yaw, and braking/accelerating shear.

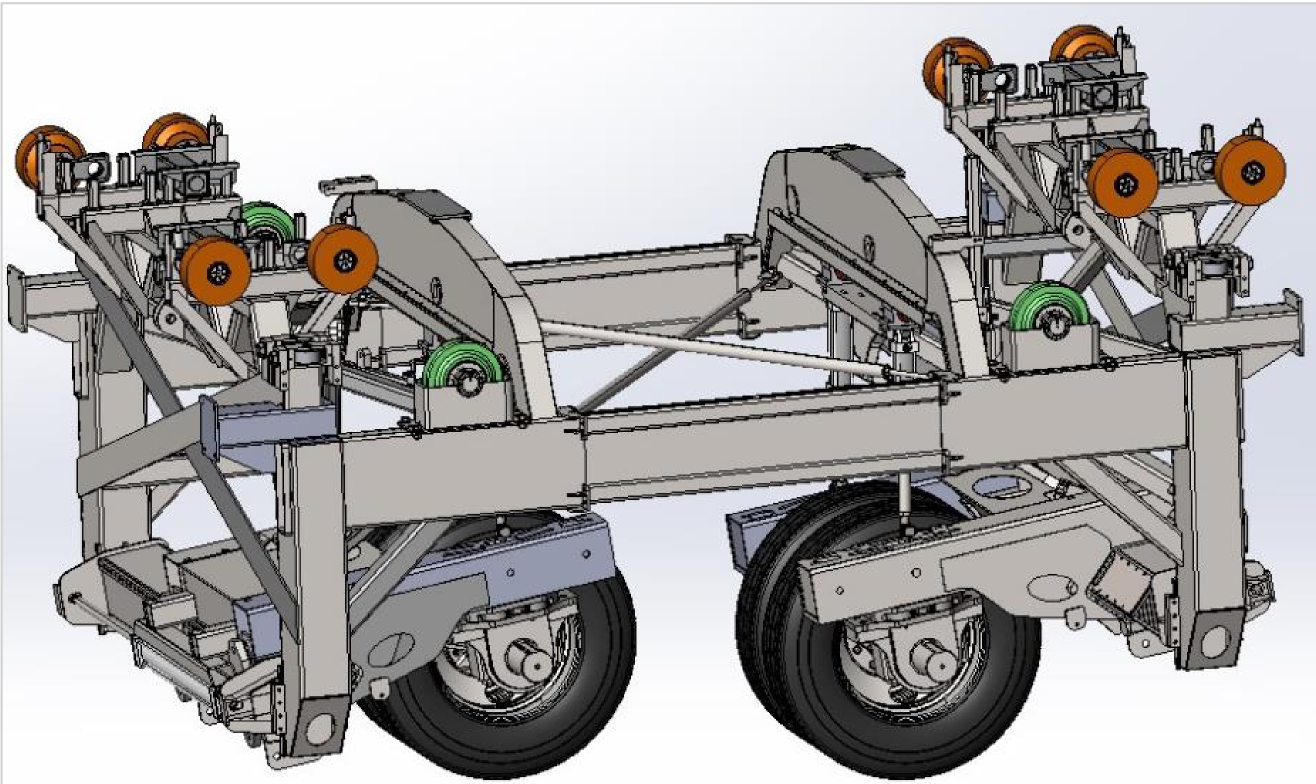


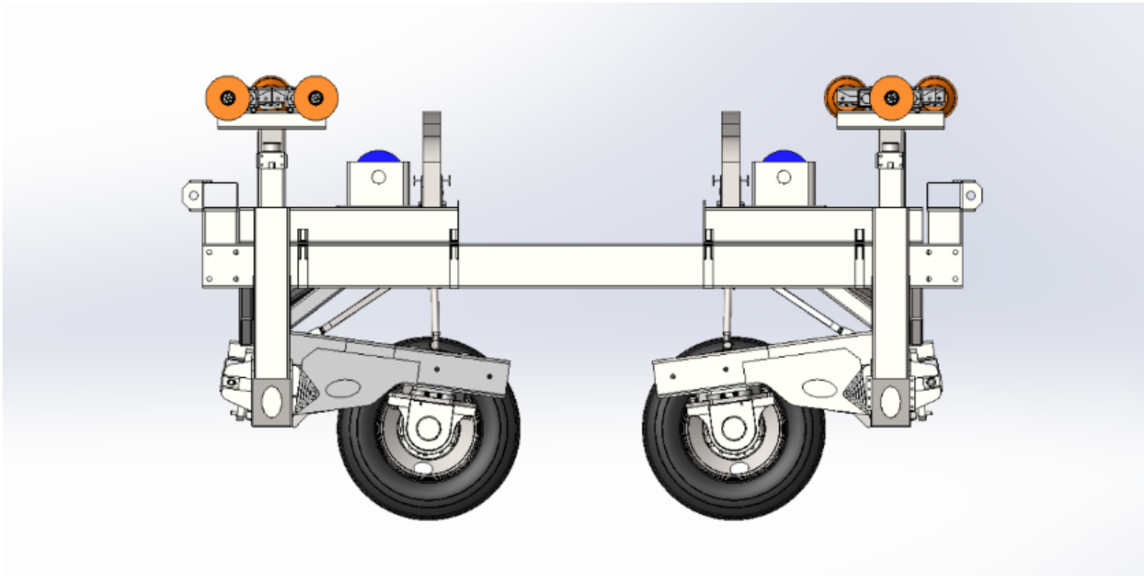
Figure 12. Illustration. Enhanced load carriage.

Tandem Axle Configuration

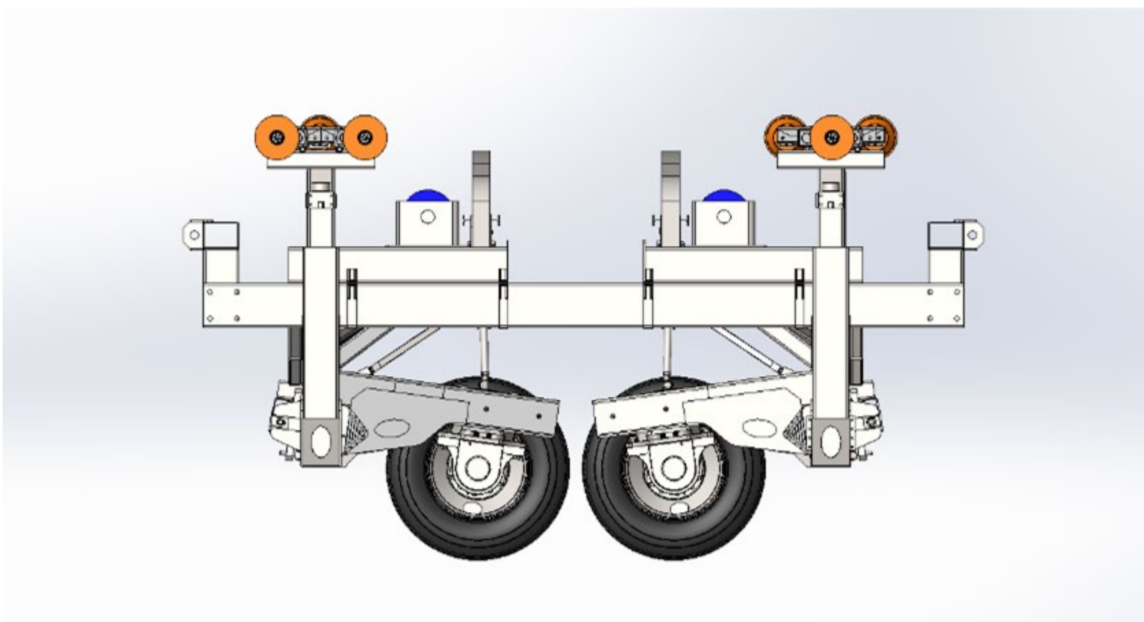
The carriage allows testing using either a single half-axle or a tandem half-axle configuration. For simplicity the word axle is used instead of half-axle in this report. A tandem axle configuration has two axles, one following the other. Various tire configurations can be installed. In real traffic, a tandem axle distributes the load equally on the two axles. In I-APT, each axle can be loaded independently. In addition, the spacing and offset of the two axles can be varied.

Axle Spacing

The maximum spacing between the wheel axles in a tandem configuration is 67.5 in., with a minimum axle spacing of 35 in. The tire size determines the minimum or maximum spacing between the leading and the trailing tire. For typical truck tires with an outside diameter of 37 in., the tread-to-tread spacing could range from 0 to 37.5 in. In bi-directional load tests, the leading tire becomes the trailing tire during the return passes. Space between tires in one axle depends on tire size and the mechanical limits of the carriage (Figure 13).



(a) Maximum axle spacing

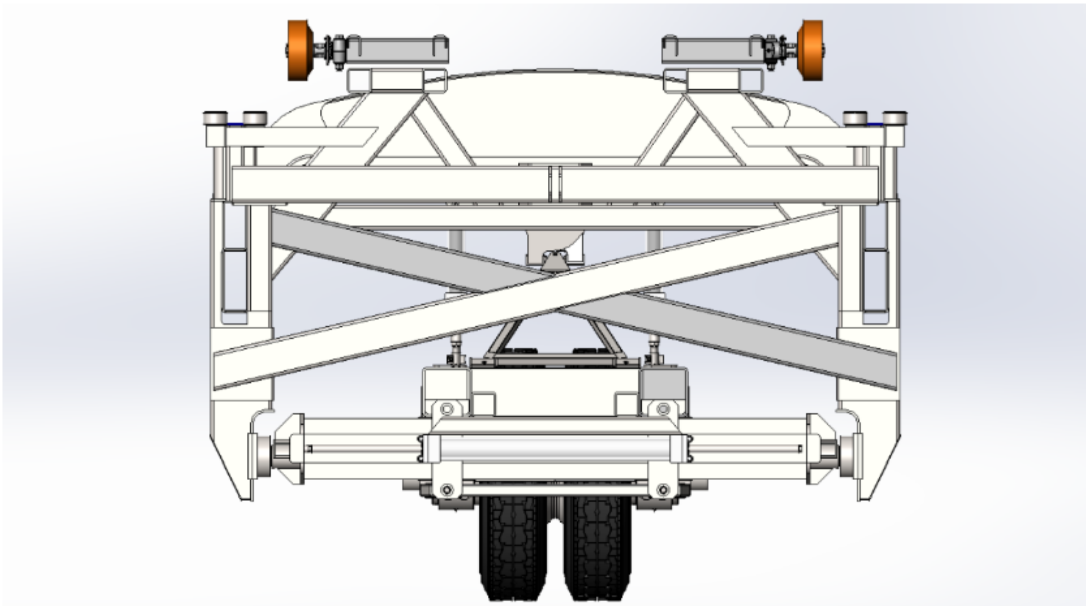


(b) Minimum axle spacing

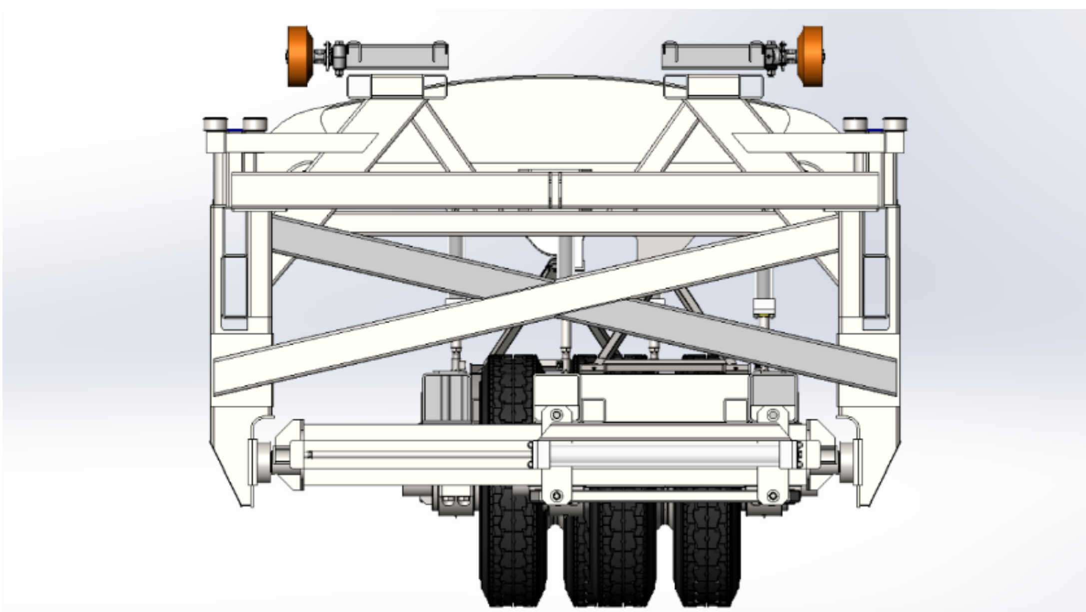
Figure 13. Illustration. Schematic of tandem axle spacing: (a) maximum axle spacing, (b) minimum axle spacing.

Wheel Offset

The offset for the two tires can vary from zero to a maximum of 18 in. Zero offset means that the leading and the trailing wheel axles are perfectly aligned, and they track over the same pavement line. The offset can be selected anywhere in the 0 to 18 in. range. Note that an offset smaller than one tire width will cause overlapping on the tracking of the two-wheel axles (Figure 14).



(a) Offset of 0 inches

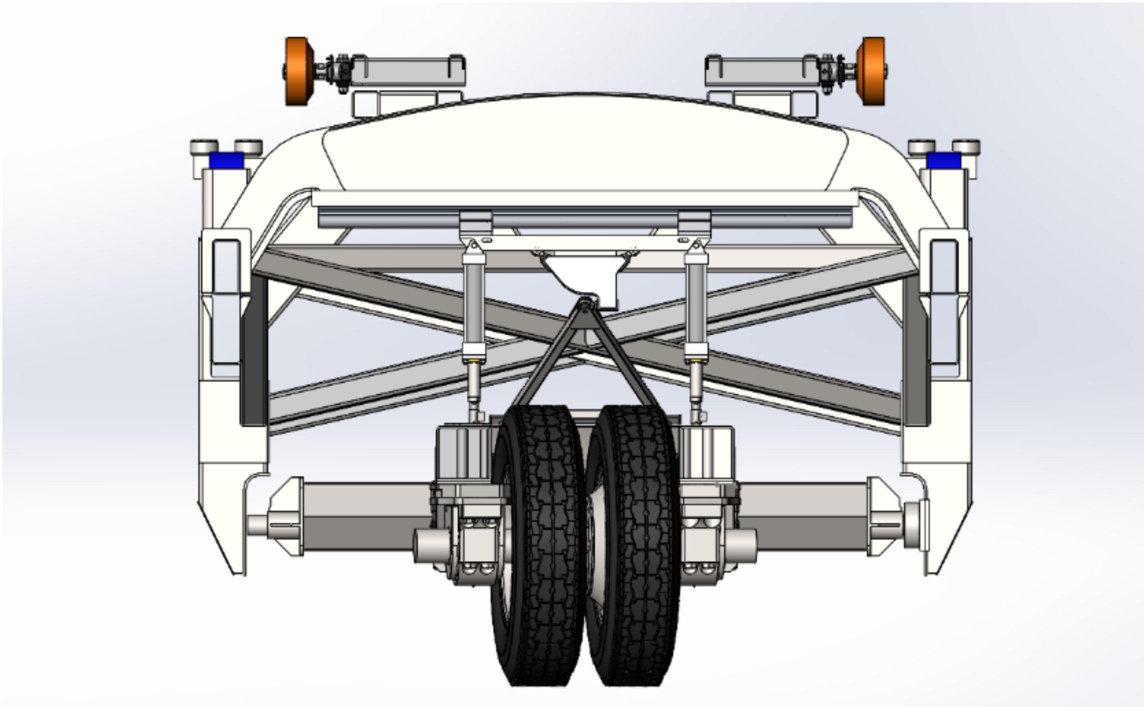


(b) Offset of 18 inches

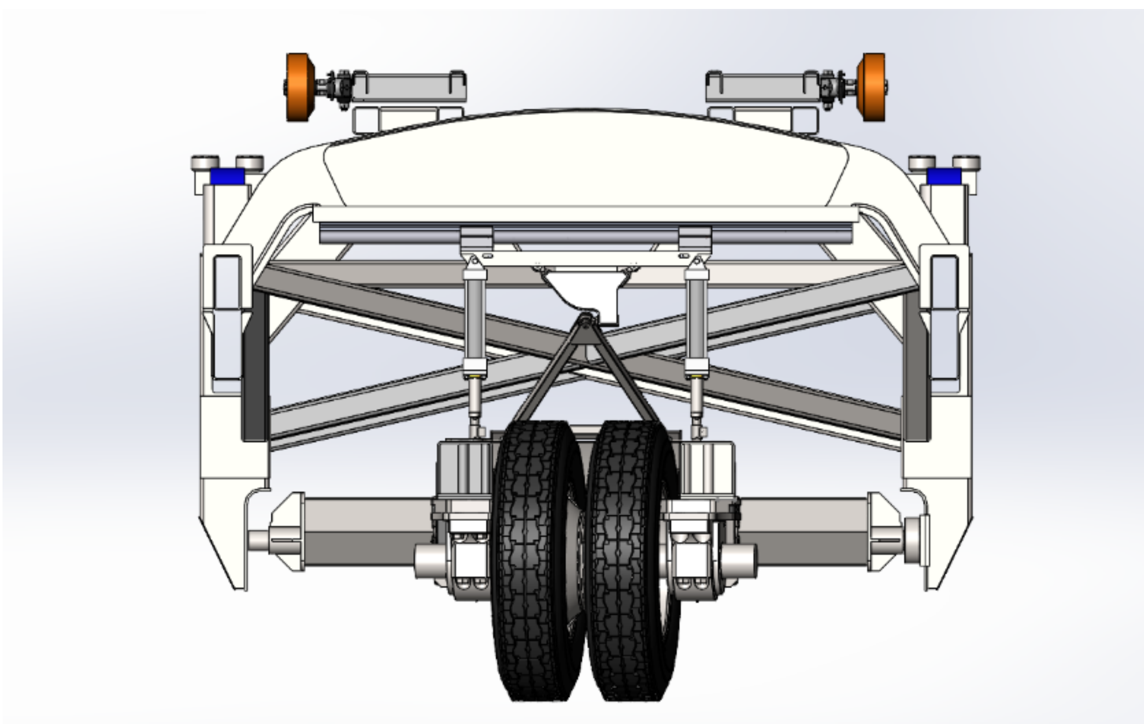
Figure 14. Illustration. Schematic of tandem axle offset: (a) offset of 0 in., (b) offset of 18 in.

Axle Yaw

Axle yaw is where the wheel's axles rotate up to 6 degrees relative to the direction of travel. Side-slip shear force can be applied to the pavement surface when trafficking under load and controlled by either normal load feedback or optionally side-force feedback. It can be turned in either direction and trafficking can occur unidirectionally or bidirectionally. To prevent overload, a limit of 7,500 lb of side-force is monitored and regulated by the control computer (Figure 15).



(a) Axle yaw of positive 6 degrees



(b) Axle yaw of negative 6 degrees

Figure 15. Illustration. Schematic of tandem axle yaw: (a) axle yaw of positive 6 degrees, (b) axle yaw of negative 6 degrees.

Shear Capability for Brake and Acceleration

The shear force application capability (Figure 16) was added to I-APT for two reasons. First, electric vehicles—equipped with in-wheel motors—apply large torque, creating greater shear stresses than conventional internal combustion engine drive vehicles (ICVs). This high torque has advantages and might be used in what is called "direct yaw-moment control" (DYC), aimed at improved vehicle handling performance and stability. Second, shear is increasingly important in evaluating performance of pavement preservation treatments, including thin overlays. Departments of transportation are increasing the use of preservation treatments consisting of thin layers that experience high shear stresses under traffic. This capability is critical in evaluating the performance of these treatments to provide data to enhance material selection, mixture design, and construction methods.

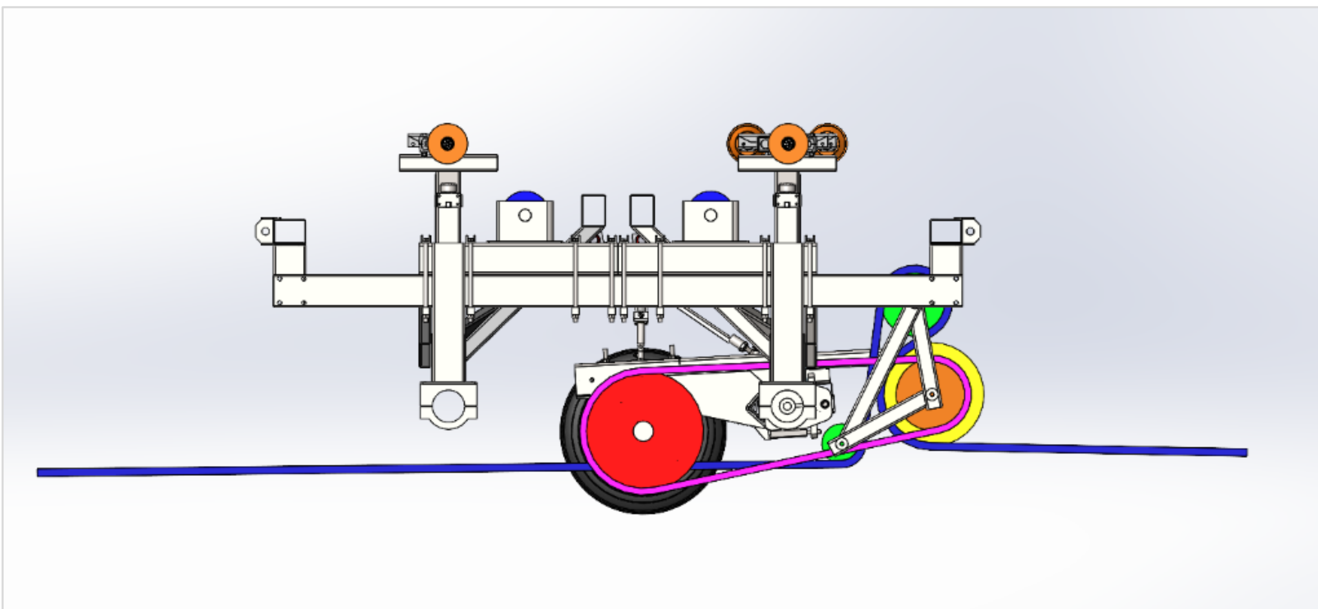


Figure 16. Illustration. Schematic of mechanism for shear capability.

The shear loading upgrade permits simultaneous wheel loading and shear loading. It produces the shear forces that would be generated by braking or accelerating at any speed, even stopping in either direction. This design uses a mechanical method that eliminates a significant portion of the force from the winch. The advantage of this method is the effort can be controlled using a lower power winch with little additional energy required. It is powered by a separate hydraulic system and handling is incorporated into the I-APT control computer. It is attached to the swing arm of the carriage and can be removed when not needed. This setup does not allow for wheel wandering and incorporates a chain that runs the length of the system. Tension applied at one end is transferred to the wheel through a series of gears, creating a shear force equal to the net tension difference, assuming a one-to-one coupling ratio. Tension is generated by a hydraulic actuator and measured with load cells on each side. Only a small amount of displacement occurs during operation, unless intentionally skidding, so the hydraulics do not need to displace the chain much, thus the low power consumption. It is not intended or designed to be used when skidding but is capable of some skidding. The tire must be firmly planted on the pavement so that the applied shear force does not result in skidding.

This mechanical method was selected because it is deemed a better choice for I-APT. Hydraulic motors were considered but they require more energy and increase the risk of test bed contamination should a leak occur.

OTHER IMPROVEMENTS

Hydraulic Power Unit

The conversion to hydraulic drive from frequency drive has eliminated electrical noise interference. This allows for accurate pavement sensor readings while the carriage is in motion, a capability not possible previously. All heat loss is now inside the I-APT area, and as such, may assist with temperature control during cold weather testing. This conversion retained the existing winch with drum and gear reducer. The hydraulic drive package includes a variable displacement pump, driven by a three-phase electric motor (150 HP, 460V). The package includes an oil tank and hoses.

Increased Crawler Power

To address insufficient crawler power, a flow divider has been implemented to distribute hydraulic power evenly to each crawler unit. The original flow divider, replaced in 2013 and known for being a weak link, was removed and replaced with a manual valve system. The manual valve system allows the user to apply an appropriate level of hydraulic power to each crawler unit for proper functionality of the I-APT propulsion system. In addition, the operating pressure of the hydraulic pump was adjusted to increase the available power.

Carriage

Lateral Wander

Lateral wonder is the characteristic of the load system that allows the wheel to track at different lateral positions (Figure 17). The original capacity ranging from −18 in. to +18 in. has been retained in the design of the new carriage, and it may be applied to the new tandem loading option.

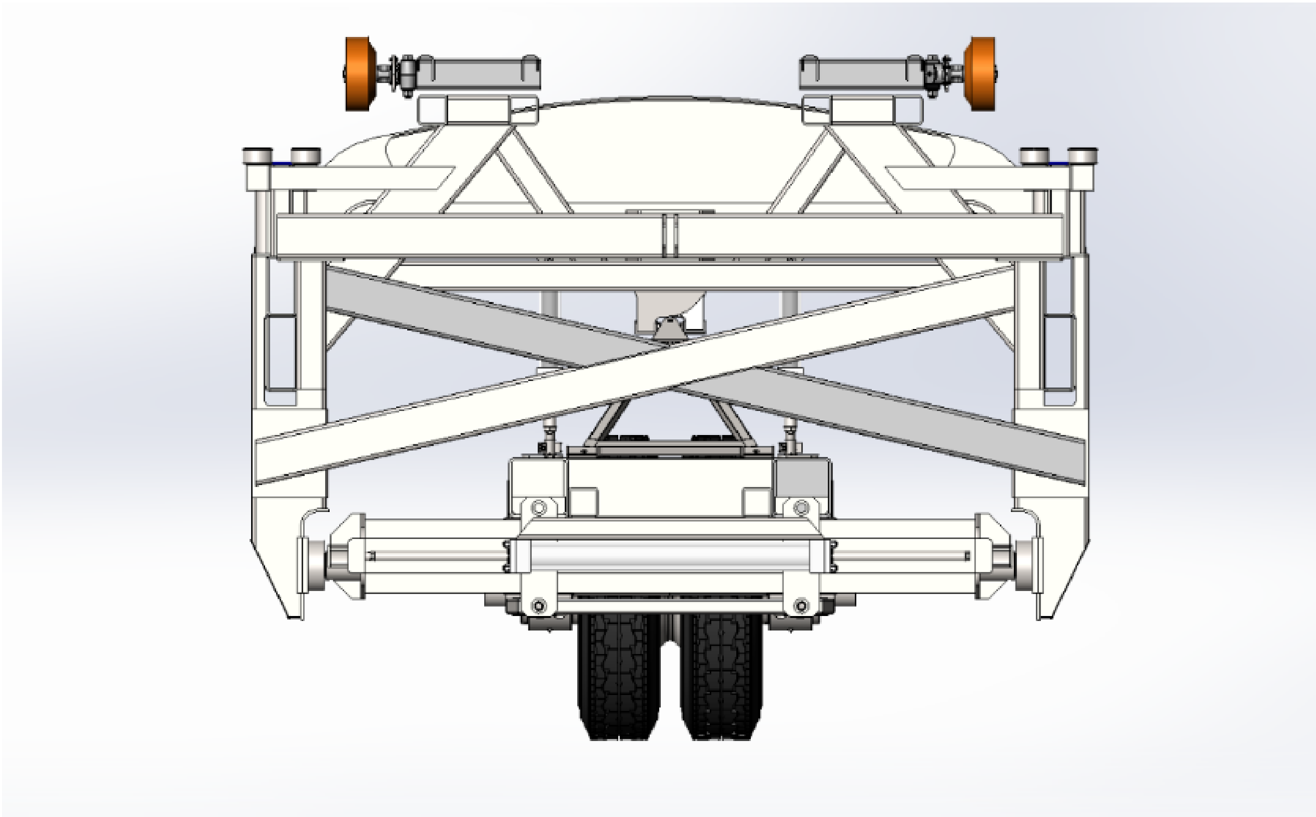


Figure 17. Illustration. Mechanism for lateral wander.

Vertical Load

Load capacity was reduced as intended. The new 3.25 in. bore cylinders provide 35,000 lb of downward force, which is less than the previous capacity of 80,000 lb. This improves accuracy and precision of the applied load.

Rail Contact

The existing return wheel mounts were replaced with a new design that uses two soft wheels at each corner of the carriage. This new design allows the carriage to maintain rail contact at lower loads. The return wheels are shown in orange, while the green wheels are the ones reacting against the rail during pavement loading (Figure 18).

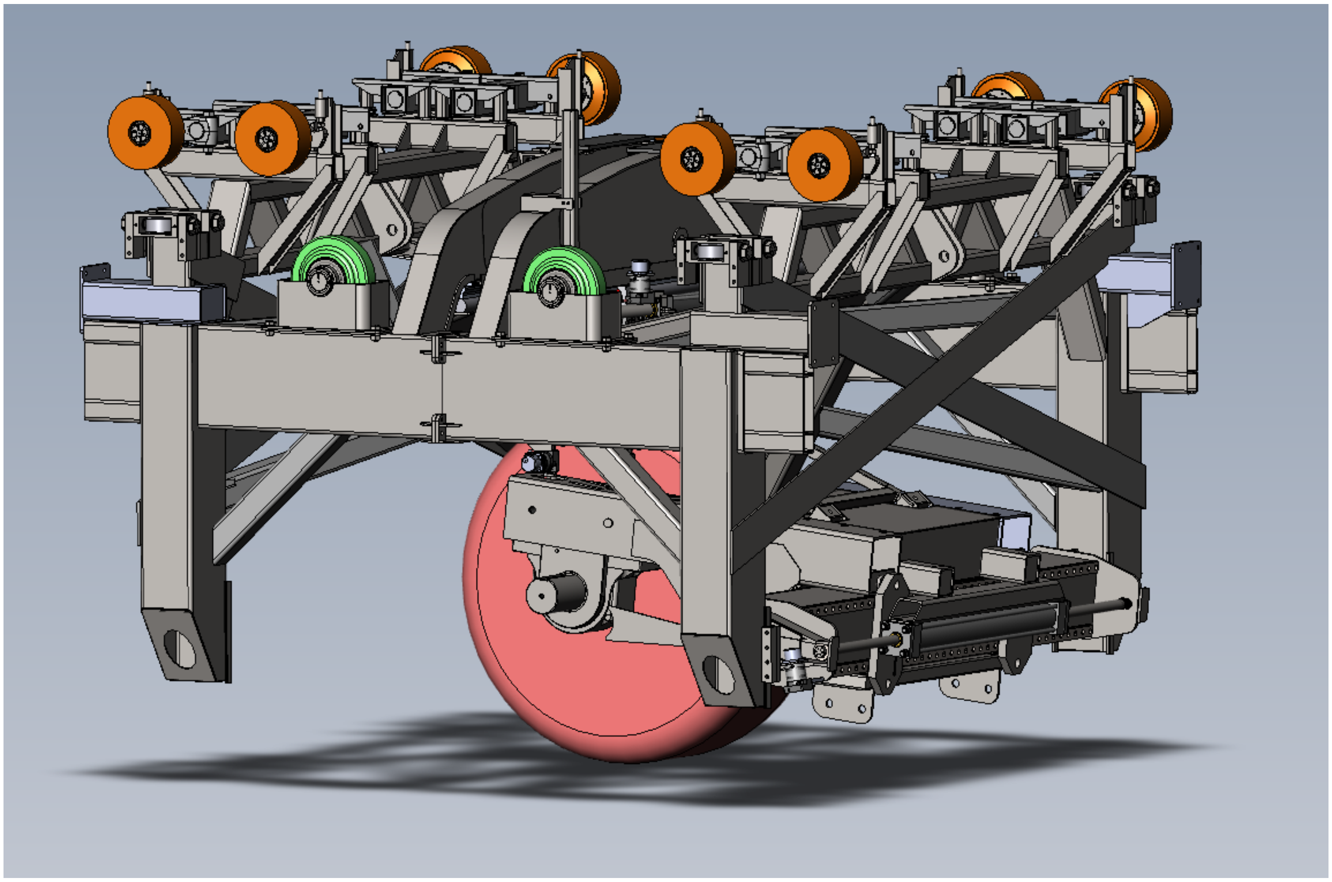


Figure 18. Illustration. Return wheels.

Control Trailer and Software

A new control trailer has been introduced, replacing the old one. The modern control system, implemented for I-APT, was written in LabVIEW, allowing ICT personnel to modify it for future research requirements. Replaced equipment includes the control computer, delta motion computer control system and cabling, and an uninterruptable power supply. The new control program features self-test capabilities before operation, continuous fault detection for maintenance and repairs, automatic shutdown in emergencies, and file management to append each run's data into a single test file.

I-APT Colors

As part of the upgrade process, the color scheme of I-APT was changed from its original yellow and black to a new combination of orange, blue, and black (Figures 19 and 20).

Figure 19. Photo. I-APT orange during painting process.

Figure 20. Photo. I-APT final orange, blue, and black color scheme.

IMAGES OF THE UPGRADE PROCESS

The installation of new parts for the upgrade began in March 2024. Figure 21 shows the swing arm being attached to the carriage frame, after the frame had been installed on the rails.

Figure 21. Photo. Swing arm being attached to the new carriage.

A front view of an aircraft tire is shown in Figure 22, while a side view comparison of an aircraft tire and a truck wide-base tire is shown in Figure 23. Two hydraulic actuators are used on each side with the aircraft tire, which allows for maximum loading. When using truck tires, only one actuator is placed on each side. The second set of actuators could then be used when tandem is used.

Figure 22. Photo. Aircraft tire front view.

(a) Aircraft tire

(b) Truck tire

Figure 23. Photo. Comparison between loading of (a) aircraft tire and (b) truck tire.

A process was followed to test the various features of the new carriage. This included setting various wheels, installing single and tandem axles, and adjusting software to control vertical and lateral loadings and positions. The steel cable was installed in July 2024 and was tested for longitudinal positioning, speed, and uni- and bi-directional loading. The last phase of the entire upgrade project has been the acceptance test, where I-APT has been applying loads under different configurations, as shown in Figure 24, before moving it to a research test section.

Figure 24. Photo. Markings during acceptance test.

CHAPTER 4: FULL SPECIFICATIONS

This chapter presents the new full specifications achieved with the upgrades (Table 2).

Table 2. I-APT Specifications

Specification	Current	Before 2023 Enhancements
Machine Dimensions	Length: 124 ft Width: 12 ft Height: 12 ft	Same
Pavement Section Length/Width	Length: 85 ft (65 ft of max constant speed) Width: Variable, typical 12 ft	Same
Machine Displacement Method	Crawler tracks, diesel powered, via remote control tether	Same
Loading Wheel Options	Varies with experiment: - Single-wheel axle, single tire - Single-wheel axle, dual tires - Tandem-wheel axle, single tire - Tandem-wheel axle, dual tires Single tire could be single truck tire, super single, aircraft tire, or rail bogey	Tandem option not available
Tire Pressure	Variable depending on tire rating	Same
Load Magnitude	From 0 to 35,000 lb When in tandem, each wheel applies up to 35,000 lb	Max load 80,000 lb. But this limit was for rail bogey, which was not used
Load Monitoring	Load cell on the loading arms	Hydraulic pressure gage, which had a low level of precision
Load Application Speed	Linear wheel speed. Up to 10 mph over 65 ft central portion	Same
Description of Load Carriage Suspension	Hydraulic suspension Rail wheel against rail when loading Two soft wheels per carriage corner when carriage is suspended	Same Same One soft wheel per carriage corner
Lateral Movement and Wander	From −18 in. to +18 in.	Same
Load Applications (One- or Two-way)	One-way (unidirectional) Two-way (bidirectional	Same
Axle Yaw	From −6 to +6 degrees	Not possible
Braking or Accelerating Shear	Yes, but not with tandem loading or lateral wander	Not possible

Specification	Current	Before 2023 Enhancements
Environmental Conditions	Yes (since 2008)	Same
Ancillary Equipment	Control trailer, new, with enhanced test visibility Mechanical trailer	Control trailer, old Mechanical trailer, same
Test Control System	LabView routine, editable Windows 11 Improved file management	Proprietary software, locked for editing Windows 2000
Running Power	3-phase electrical	Same

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