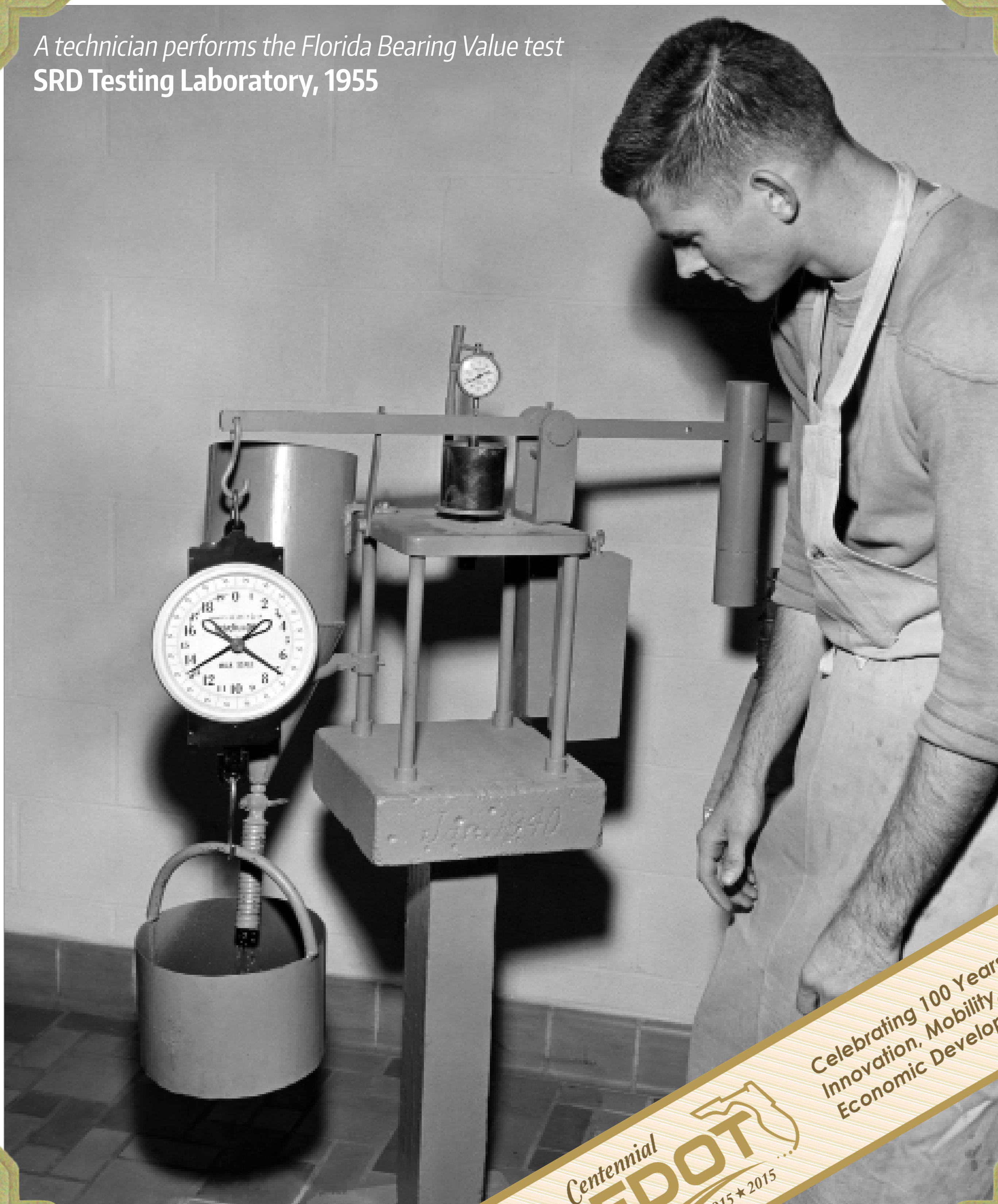
FALL 2015

florida department of transportation

Research Showcase



A technician performs the Florida Bearing Value test
SRD Testing Laboratory, 1955

Celebrating 100 Years of Innovation, Mobility, and Economic Development

Centennial FDOT 1915 ★ 2015

florida department of transportation

Research Showcase

The Florida Department of Transportation *Research Showcase* is published to provide information regarding the benefits of FDOT-funded research.

Managing Editor
Darryll Dockstader

Editor
Jessica VanDenBogaert
jessica.vandenbogaert@dot.state.fl.us

Writers/Graphic Design
Charles Brown
Jessica VanDenBogaert

Printer
Target Printing

Front Cover
A technician performs the Florida Bearing Value Test in the State Road Department Materials Laboratory
floridamemory.com

Governor
Rick Scott

Secretary of Transportation
Jim Boxold

FDOT Research Center
605 Suwannee Street, MS 30
Tallahassee, FL 32399-0450
(850) 414-4615
http://www.dot.state.fl.us/research-center/

Centennial FDOT 1915 ★ 2015

IN THIS ISSUE

As we approach our centennial anniversary, we take this time to look back at the advances in transportation knowledge and practice made by the Florida Department of Transportation and its predecessor, the State Road Department.

In 1916, in a borrowed room at the University of Florida, a handful of technicians began testing the materials being used to build and improve Florida roads. This foray into research has since grown into a multi-million dollar research program. Today, we fund pioneering applied research that seeks to improve all aspects and modes of transportation.

We have come a long way in a hundred years. Join me as we look back at a century of research and innovation in the Sunshine State.

- Darryll Dockstader

THE FLORIDA DEPARTMENT OF TRANSPORTATION HAS OFFICIALLY REACHED ITS CENTENARY.

Over the past 100 years, as the state of Florida experienced remarkable population growth and technological change, the Department would also change and grow.

From its beginnings in 1915 with a handful of engineers in an unused office in the State Capitol in Tallahassee, dispensing advice and assistance to counties seeking to build roads, the Florida Department of Transportation has become a dynamic, multi-modal agency, working to provide a quality transportation network that is moving Florida into the next century.

Today, FDOT is a national leader in applied transportation research, with a research program that tackles a wide variety of issues and works to advance transportation science and practice. The research program of FDOT has deep roots - research activities were established in its first year - and has changed and grown as the needs of the people of Florida have changed and grown.

From Good Roads to the State Road Department

Around the turn of the twentieth century, the Good Roads movement was growing across the country. With the rise of the bicycle and later the automobile as popular forms of personal transit as well as the continuing trend towards urbanization, people began to understand the need for improved infrastructure and good roads.

Before the establishment of the State Road Department, road-building was strictly a local concern. Outside of the major cities, roads were often unimproved dirt, sand, or clay whose construction and maintenance was often left to the landowners abutting the road. Citing the economic benefits of road paving and mass transit like railroads and trolleys, Good Roads advocates began lobbying the various levels of government to either begin or expand their road-building activities. New Jersey became the first state to pass a law providing for state-level participation in road-building projects.

The Good Roads movement eventually moved south into Florida. In 1914, the Florida State Roads Convention was held in Gainesville, formally establishing the Florida State Good Roads Association (FSGRA) and aligning it with the larger Southern Good Roads Association. The FSGRA began a concerted publicity and lobbying effort, publishing articles in newspapers across the state lauding the unique features of Florida and the benefits that could be had for both residents and visitors alike if roads were built and improved.

A sympathetic legislature listened. The State Road Department was established by Act of Legislature in 1915 and became operational on October 1, 1915. Originally, the Department was to act as an advisory body to the 52 counties of Florida, assembling maps and information on existing roads. The members of the Department, five in total, would be appointed by the Governor and provide guidance on the work of the Department.

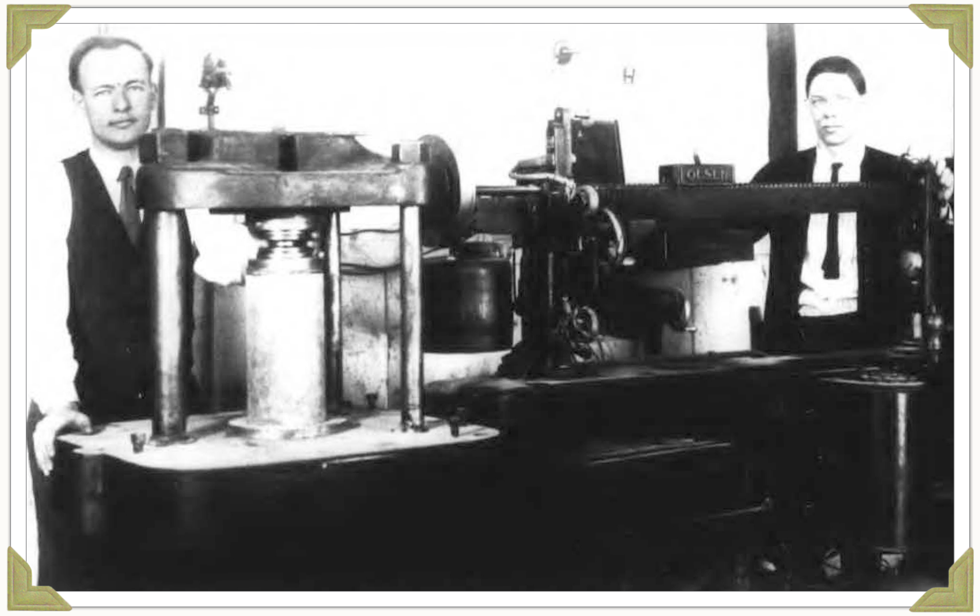
At 3:30 pm on Friday, October 8, 1915, four of the five members of the State Road Department (J.D. Smith of Marianna being absent due to illness) met in the Senate Chamber of the State Capitol to begin the work of building and maintaining roads in the State of Florida. The first order of business: select a chairman and a secretary. Ed Scott of Arcadia was named the chairman, and J. D. Smith of Marianna was selected as the secretary.

The Testing Division is Established

At the second meeting of the Department, a letter from Dr. J. R. Benton, Dean of the College of Engineering at the University of Florida, was read. Dr. Benton offered office space, equipment, and personnel free of charge in order to locate the Engineering Division of the Department at the University. It was not until the next year, 1916, that newly chosen Commissioner William J. Cocke would take up Dr. Benton on his generous offer and establish a testing laboratory at the College of Engineering at the University of Florida.

> “The laboratory, I believe, is essential to the usefulness of the Department as we are daily asked to pass upon road building materials, and without the laboratory equipment, any opinion we may venture is purely guesswork.

The work of this laboratory would be the very first research activity undertaken by the Department. In a letter to the members of the State Road Department, Commissioner Cocke expounded on the importance of testing activities, “The laboratory, I believe, is essential to the usefulness of the Department, as we are daily asked to pass upon road building materials, and without the laboratory equipment, any opinion we may venture is purely guesswork.”



1925-26: Some of the equipment used to test materials at the Testing Division laboratory in Gainesville.

Between 1921 and 1925: State Road Department chairman Henry Phillips and staff outside their office in Tallahassee.
Source: Florida Memory

Harvey A. Hall was hired as the first Testing Engineer. In preparation, Hall was sent to Washington, D.C., to work in the testing laboratory of the Federal Bureau of Public Roads for two months before returning to “a large room on the ground floor of the old Engineering Building for the State Road Department Laboratory.” Once equipment arrived, Hall and the testing engineers of the State Road Department began to test materials being used in road construction around the state.

This type of routine testing would ensure that materials used in construction and maintenance met the standards and specifications set by both the State Road Department and the Bureau of Public Roads. During 1927 and 1928, over 11,000 tests were made of concrete, Ocala and oolite lime and Ojus rock, asphalt mixtures, fine and coarse aggregates, concrete cores, samples of asphalt, cement and tar, and samples of water, iron, and paint.

By 1929, the Testing Division included the laboratory in Gainesville and branch laboratories located in Marianna, Williston, and Ocala. Field laboratories were also established at the site of large bridge and paving projects. According to Hall’s successor, H. C. Weathers, the work of the testing laboratory consisted of routine tests of samples solicited from projects under construction, checking the surface and bore samples of bases and concrete pavements for conformity with specification requirements.

While no specific charge to find new methods and new materials would be given for another thirty years, the staff of the Testing Division, later the State Materials Office, would tackle tough questions and establish a national presence as a leader in materials research. This type of materials testing continues unbroken to the present day.

The Cornwall Two-Way Road –The First Experiment

The Testing Division of the State Road Department (SRD) was not explicitly tasked to perform investigatory research into new or innovative solutions. It was up to manufacturers and inventors to bring their new ideas to the SRD.

In 1919, S. N. Cornwall approached the Board of the State Road Department with his method for concrete highway construction. Cornwall’s method differed significantly from the methods then being used by the State Road Department. The Department was building nine-foot-wide roads of sand-clay, macadam, shell, or asphalt, whereas the Cornwall system consisted of three or four strips of concrete, laid parallel, to allow two-way traffic to pass each other in a 16-foot-wide span.

At the May meeting of the Board of the State Road Department, a resolution was passed to build an experimental stretch of “a reasonable mileage” in order to ascertain the wearing capabilities of Cornwall type construction. This resolution was the very first research project undertaken by the State Road Department that was outside the realm of ordinary materials testing.

For reasons that are not preserved in the record, the Cornwall road experiment was never undertaken by the State Road Department. The resolution was rescinded two months later, before the road was built. However, some ideas taken from the Cornwall road system were implemented. The two-way, sixteen-foot road became the official width of state roads the next year.

BREAKING NEW GROUND AND ESTABLISHING A NATIONAL PRESENCE

Though no specific budget or staffing had been assigned to experimental research, the State Road Department still sought answers to the problems they encountered when building and enhancing the roads in Florida. This included studies into Florida lime rock, corrugated metal culverts, the sources of concrete pavement cracks, and even the types of paints that work best in Florida's unique weather conditions. The increasing research activity would lay the foundation for a robust research program and an emerging national presence.

Sand-Asphalt, Mixed in Place

Road building in Florida faced unique challenges. Rock and gravel are not naturally abundant, especially in South Florida. There were no brick manufacturers within the borders of the state. Freight rates were prohibitively expensive, and funding was always in short supply. As the State Road Department entered the road building business, engineers began looking for a road stabilization process that met requirements for strength, ease of construction, and low cost.

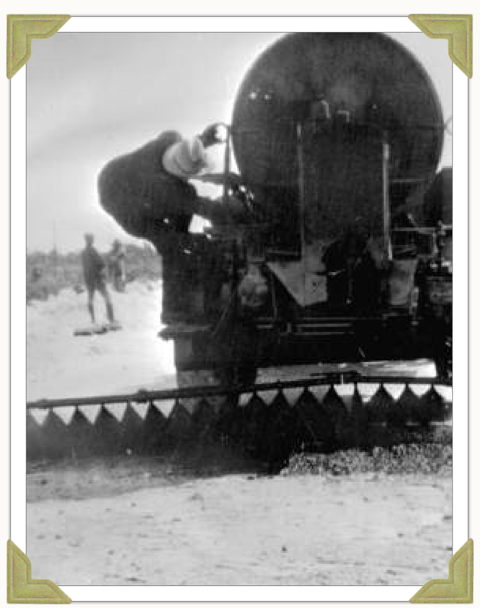
According to a 1916 edition of Popular Mechanics, "sand asphalt" was being used by some Florida counties to stabilize rural roads. Sand-asphalt is created by mixing liquid asphalt with sand, which is then poured over a prepared roadbed of clay or shell. This method of paving was much cheaper than other methods and was easily available across the state. However, results proved too inconsistent for use on state roads. Sand-asphalt roads were still unstable and prone to rutting and sinking. A letter to the editor of the St. Petersburg Daily Times in April 1917, labeled sand-asphalt roads "a disastrous experiment" and far inferior to the "old, stable, well compacted Bartow clay streets."

However, sand-asphalt proved too tempting to ignore. Florida in the 1920s was prime for a cheap method of road building that would stand up to the climate and geotechnical conditions. The vast majority of roads would not see high traffic volume but were necessary to connect the growing cities and towns of the state.

The engineers of the State Road Department, specifically H. C. Weathers and the staff of the Testing Division, set to work to improve and better utilize this economical method of road stabilization. Experiments were conducted with base materials and asphaltic oil combinations that were then laid in test roads in West Florida until a number of suitable combinations were decided upon and implemented.

A sand-asphalt road was created thusly: the existing road material, typically sand or silty sand, is mixed uniformly by harrow or grader then compacted with rollers. Then, bitumen, cut with naphtha, is applied to the roadbed and plowed into the sand for a depth of seven or eight inches. The resulting mixture is then graded, compacted and rolled. By 1930, the improved sand-asphalt road became the method of choice for the State Road Department's low-volume roads.

1917: A road crew lays base material in preparation for mixing and spraying for a new 9-ft road near Mulberry.
Source: Florida Memory



1917: Asphaltic oil is sprayed on a prepared roadbed to create a sand-asphalt road.
Source: Florida Memory

1917: A county-built sand-asphalt road near Mount Dora showing typical wear patterns and ragged shoulders.
Source: Florida Memory

1928: A road crew adds material to stabilize the subgrade of a road bed in Marion County.
Source: Florida Memory

1955: An unidentified man performs the Florida Bearing Value test in the Bearing Value and Compaction room at the SRD Testing Laboratory in Gainesville.
Source: Florida Memory

Subgrade Stabilization and Florida Bearing Value

As the State Road Department expanded its road-building work, the unique geography of Florida also challenged the engineers to look under the road for answers. Sand-asphalt was proving very useful as a surface course in sparsely populated areas, but the subgrade and base layers were less consistent. Some newly built roads were constructed easily, but others proved challenging.

A road near Fort Walton provided a perfect experiment. The road would simply not harden. After the road was completed and compacted with rolling equipment, vehicles that were allowed to sit on the pavement for more than a few minutes would begin to sink. The Testing Division was dispatched to investigate.

Tests indicated that the road surface, being mostly ordinary beach sand, was inherently unstable as the grains of sand were too uniform in size and too rounded. The sand was simply not angular enough to interlock and create a stable roadbed. This was a major problem. It would not be feasible to construct a road only to discover that, because of the sand used in it, it was not capable of supporting the weight of vehicles. Back at the laboratory, the Testing Division tackled this problem. Only well characterized materials would lead to predictable construction. They devised a machine later dubbed the Florida Bearing Machine. This was a lever-type machine in which a sample of material was placed with a one-inch round bearing plug resting on the surface. Pressure would be constantly increased until the bearing plug sank into the material. This amount of pressure in pounds per square inch was deemed the bearing point.

Using the Florida Bearing Machine, verification tests of high-performing roads were conducted to determine an appropriate bearing point level. These results were then applied at the Fort Walton project. A new source of coarser, angular sand was incorporated into the road bed, and bearing point tests determined that the resulting weight-bearing capacity was sufficient to withstand the weight of traffic.

This bearing point measure, dubbed the Florida Bearing Value, was incorporated into Department specifications for stabilized roads. The result was construction that was deemed "most satisfactory... from the standpoints of economy, durability, and riding qualities." The Florida Bearing Value proved just as durable – the measure continues to be used in limited applications to the present day.

WAR IS OVER: RESEARCH EXPANSION

World War II and its drain on both people and resources severely hampered the State Road Department's activities, including research. The Department operated on a shoestring budget and skeleton staff. However, post-war prosperity, surplus materials, and a massive influx of new residents and tourists fundamentally changed both the state and the State Road Department. New roads needed to be built quickly, old roads needed to be improved, and waterways needed to be bridged. The Department needed new and innovative ways to plan, design, and build the infrastructure needed to support the fast-growing population in the state.

As such, the 1950s were a time of great expansion and success for the research activities of the State Road Department. For the first time, a specific division and staff were dedicated to research activities. Universities were contracted to perform larger research projects, and the advances made during the decade would resonate to the present time.

Roadway Design Criteria and the Limerock Bearing Ratio

The year 1955 was a time of change for research at the Department. The Division of Materials moved into a new testing facility in Gainesville, and a separate Division of Research and In-Service Training was established. A small experimental laboratory was established also, and a staff of nine engineers and nine technicians was assigned to work solely on research projects.

One of the first projects undertaken by the newly staffed Division of Research was to continue development of flexible pavement criteria using a Florida-specific modification of the California Bearing Ratio. Around 1930, at about the same time that Florida State Road Department researchers were developing the Florida Bearing Value test for sand road base, the California Department of Transportation had been working in a similar vein to develop a testing procedure to determine the mechanical strength of non-sand road subgrades. The California Bearing Ratio (CBR) proved very popular and was ultimately adopted by several states and the Bureau of Public Roads. However, due to the unique nature of Florida's geology, the CBR was of limited value to engineers in Florida.

Over three years, eighty-four different flexible pavement sites were evaluated across the state. All sites had been in use for more than ten years and had a high traffic count. Researchers measured the density, moisture content, and bearing capacity of each layer of material and correlated the results with the perceived performance of each road.

> "This test was so successful that the Federal Bureau of Public Roads accepted the LBR design criteria for the structural design of all interstate projects.

In west Florida, bases were primarily shell, stabilized shell, and sand-clay, for which the Florida Bearing Value tests were useful. However, in east and south Florida, various types of limerock were most commonly used as road base and were not applicable to the Florida Bearing Value or the California Bearing Ratio tests.

As part of the development of design criteria, penetration tests were performed on the different types of limerock. Acceptable values were established for each of the different types of limerock and incorporated into the revamped design criteria. These values became the basis for the Limerock Bearing Ratio (LBR). This test was so successful that the Federal Bureau of Public Roads accepted the LBR design criteria for the structural design of all interstate projects. The LBR has continued to be refined through further research and is still in use today to evaluate materials.

Pre-Stressed Concrete

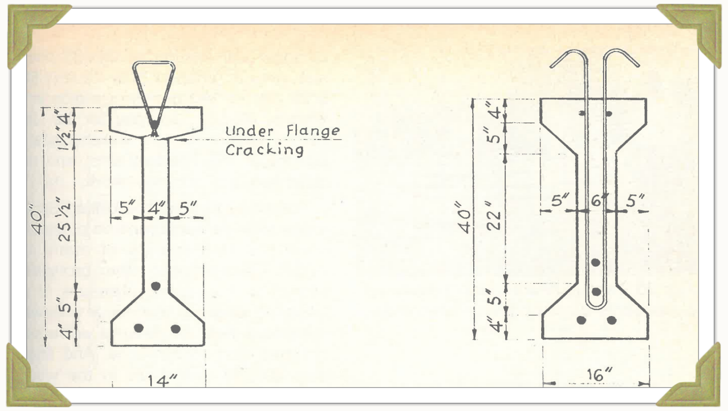
Today, concrete is ubiquitous in structures, especially in Florida, due to the aggressive environmental conditions that structures must endure. The Victory Bridge over the Apalachicola River at Chattahoochee, completed in 1922 and one of the first flagship projects completed by the State Road Department, was constructed of reinforced concrete arches. However, due to the limitations of reinforced concrete, the spans ultimately proved too short for the constantly growing size of ships on Florida's navigable waterways.

Enter pre-stressed concrete. Like reinforced concrete, pre-stressed concrete was developed in Europe and adapted by American engineers. Pre-stressed concrete is reinforced concrete in which high-strength wires are stressed under pressure before the concrete is placed. The concrete and steel then bond, increasing the tensile strength of the concrete. This allows for smaller, lighter concrete structures that can carry a much greater load.

William E. Dean, FDOT State Bridge Engineer from 1948 to 1962, observing the successes of the first pre-stressed concrete bridge in America – the Walnut Street Bridge in Allentown, PA – advocated the use of prestressed concrete in bridge construction. He introduced prestressed concrete slabs into the state system as a durable replacement for timber decks along the Tamiami Trail. Dean also challenged engineers to use prestressed concrete in the construction of the first Sunshine Skyway Bridge. Using prestressed concrete could increase the individual approach span lengths from 36 to 48 feet, reducing the number of substructure units needed and increasing the amount of navigable waterway in lower Tampa Bay.

During the design phase of the first Sunshine Skyway Bridge, it was determined that the European style I-beams currently in use were not well-suited for assembly-line fabrication. The thin cross-section invited cracking that was difficult to control. Through the course of research and experimentation, "short and stubby" beams added only a small amount of concrete but substantially reduced cracking. Eventually, the Bureau of Public Roads and the American Association of State Highway Officials adopted this beam design for use in pre-stressed concrete bridge decks.

In addition to development of the "stubby" beam, the State Road Department sponsored research projects at universities to perform continued research and tests on the short- and long-term behaviors of prestressed members. Over the next decade, the use of prestressed concrete continued to grow until it was the predominate type of concrete used in Florida bridges.



1954: A European style I-beam (left) and a Florida I-beam (right). The Florida I-beam has continued to undergo further revisions and improvements.
Source: Reflections on the Beginnings of Prestressed Concrete in America

1963: The original Sunshine Skyway, spanning Lower Tampa Bay from St. Petersburg to Manatee County, showcased the use of prestressed concrete and spurred designers and engineers to refine and enhance prestressed concrete for structural applications.
Source: Florida Memory

BECOMING THE FLORIDA DEPARTMENT OF TRANSPORTATION

As the population continued to grow and Florida's predominately rural population became increasingly urban and concentrated in South Florida, the transportation infrastructure came under more and more strain. Approximately eight different state agencies controlled various parts of the transportation system, and little coordination existed among them.

In 1968, a new Florida Constitution was ratified, replacing the Reconstruction-era document of 1868. New legislative districts were created, reshuffling the voting power to more accurately reflect the people of the state. The next year, the modernization effort extended to the agencies of state government. Prior to reorganization, Florida had 125 separate state agencies. After reorganization, these had been consolidated into 25 – including the Department of Transportation, which absorbed the old State Road Department in its entirety.

NCHRP Is Established

By the early 1960s, most individual states were pursuing applied highway research in some form. However, there was little collaboration among the states, research efforts had become highly duplicative, and individual states often lacked the funding to pursue the larger, broader research topics. Though organizations like the American Association of State Highway Officials and the Highway Research Board worked to bring the work of transportation officials together, there was still a highly decentralized approach to research.

By the early 1960s, HRB had nearly completed administering the groundbreaking AASHO Road Test, the single largest cooperative research effort at the time. Using funds pooled from state and federal agencies, the Road Test was the first national study to examine the impacts of truck loads on different asphalt and concrete pavement designs.

On June 19, 1962, AASHO, the Bureau of Public Roads, and the National Academy of Sciences founded the National Collaborative Highway Research Program – NCHRP. In the first year of the program, thirty-four projects were initiated, valued at $3.5 million.

Since its establishment, the NCHRP program has produced research on a staggeringly wide variety of topics, including novel traffic engineering solutions, infrastructure security, safety, environmental management, maintenance, and construction techniques and materials. FDOT has participated in NCHRP since its establishment and continues to actively support the program today.

Skid Resistance and the Florida Skid Trailer

Like its participation in NCHRP, the Florida Department of Transportation has long taken pride in its involvement in solving issues on a national level.

In 1958, the Virginia Highway Department sponsored the first International Skid Prevention Conference, a gathering of industry and government experts to discuss the need to prevent skidding on pavements. At the time, several methods were used to measure skid resistance. At the conference, the results of a correlation study were released, demonstrating widely differing results from the common skid resistance measures. As a result, the American Society for Testing and Materials (ASTM) organized a committee of experts to improve these test methods.

Four years later, the ASTM committee organized another correlation study – this time using both old methods (stopping distance) and new ones (British Portable Testers and skid trailers). Data were collected and analyzed, and two test methods were developed, one specifying the use of a two-wheel trailer and one using a British Portable Tester. At the behest of the committee, the Florida State Road Department agreed to construct a pilot model skid trailer in accordance with the specifications of the test method. Other state highway departments and private organizations also built skid trailers to find the best method measuring skid.

1968: Developed by the State Road Department Division of Research, the Florida Skid Trailer was involved in a nationwide study of skid measuring devices.
Source: American Society for Testing and Materials

2015: Today, the Fricition Evaluation Unit at the State Materials Office is much more high-tech.

In 1967, the Florida State Road Department, in coordination with the Bureau of Public Roads, hosted a skid correlation study to compare the results of the various skid trailers on loan. Testers were sent from the National Aeronautical and Space Administration (NASA), the Virginia Highway Research Council, Ford Motor Company, the Louisiana Department of Highways, the Bureau of Public Roads, General Motors, Goodyear Tire and Rubber Company, the Portland Cement Association, the Stevens Institute of Technology, the Maryland State Highway Commission, and the Tennessee Highway Research Program.

At Dunnellon Airport in Marion County, the skid trailers, stopping distance vehicles, and portable testers were compared at 20, 40, and 60 mph over three different types of pavements. The results from the various test vehicles were then compared to attempt to create a universal test method for skid characteristics. While the individual trailers produced generally the same results each time, more calibration was needed to create a universal skid trailer.

The Florida skid trailer produced consistent results and performed admirably. The skid trailer was heavily used to develop new pavements. By the early 1970s, the FDOT Office of Materials and Research had used the skid trailer to develop recommendations for eight different wearing courses to upgrade the skid resistance of the state's roadways.

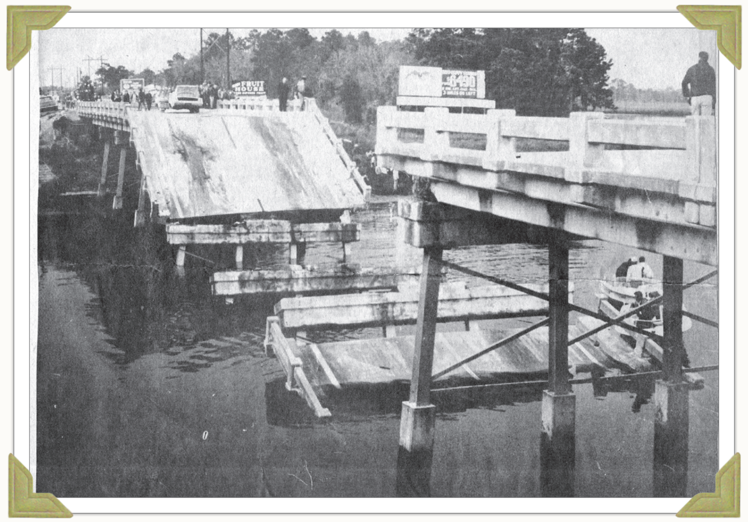
Major Advances in Cathodic Protection

On December 17, 1968, a two-lane span of US-19 over the Anclote River collapsed. While initial investigation pointed to a sinkhole in the river bed as the cause, further investigation discovered that significant corrosion of the reinforced concrete components had also contributed to weakening the bridge. Inspection of other bridges found similar corrosion problems.

FDOT took these results very seriously and immediately took steps to combat the corrosion problem long-term. The Office of Materials and Research hired a corrosion expert and founded the corrosion section to intensely study corrosion and identify and implement methods to combat this pervasive problem.

Cathodic protection, following its first use on a California bridge in 1959, interested the staff of the corrosion section. They immediately began investigating ways to implement and improve this method of protection. Cathodic protection is a technique used to control corrosion of metal by making the metal to be protected the cathode of an electrochemical cell – essentially the "positive" node of a battery. A very simple method of cathodic protection connects the bridge reinforcement to a more easily corroded sacrificial metal, typically zinc, which acts as the anode. The zinc will then corrode, protecting the bridge structure.

Since its establishment the corrosion section of FDOT has pioneered and worked to perfect many elements and methods of cathodic protection. This includes the use of zinc penny sheets,



1968: Newspapers across the country reported the bridge collapse.
Source: St. Petersburg Times

Approx. 1987: Conductive rubber was developed by FDOT and first used in 1987 on the piles of a bridge carrying US-90 in Jacksonville.
Source: NCHRP Synthesis 398

the creation of conductive rubber, the use of zinc mesh in jackets, the application of arc-sprayed zinc above tidal zones, and the use of bulk anodes on marine pilings. This extensive research has lowered the maintenance needs of Florida's bridges and, on average, extended their service life by 20 years.

Structures in the Water: Pier Scour

Florida has over 6,700 bridges in the state highway system alone. Most are small and unobtrusive while others are showpieces that have become symbols for the state. Both large and small bridges – with the exception of the only suspension bridge in Florida over the Suwanee River in Lafayette County – rely on piers and foundations to provide support for the bridge deck. These piers are then susceptible to scour – the erosion of sediment from around the piers – which can then compromise the integrity of the structure.

During the design phase, the amount of scour over time is estimated using equations, and adjustments are made to mitigate the risk. However, the prevailing national standard equations for estimating scour were proving to be inaccurate for Florida's widely varying geologic conditions. Some bridges were being built on loose, sandy soils while others were on limerock or a sand-clay mixture. As a result, bridges were being overdesigned and incurring much higher costs. FDOT, in a series of projects with the University of Florida, began researching improvements to these equations to more accurately predict scour.

First, the rate of erosion of the different types of foundational materials found in Florida had to be evaluated. Two different testing devices were created: the Rotating Erosion Test Apparatus (RETA) and the Sediment Erosion Recirculating Flume (SERF). RETA tests rock core samplings, and SERF evaluates clays, silts, and soil/sand mixtures for erosion rates. The information obtained from these two instruments was then incorporated into improved scour equations. Refinements continue to be made to increase the accuracy of the scour prediction equations. While great strides had been made in predicting scour at simple piers, more complex bridge shapes and buried or exposed pile caps are more difficult to accurately predict. However, through continued research, the FDOT bridge scour equations have proven highly effective, allowing designers to create the right type of bridge foundation for the site without costly overdesign or unsafe underdesign.

> "Through continued research, the FDOT bridge scour equations have proven highly effective, allowing designers to create the right type of bridge foundation without costly overdesign or unsafe underdesign.

(pull quote above repeats body text)

Photos from past research projects show varying levels of scour around both a simple and complex bridge pier structure. (BD545-34)

FROM MATERIALS TO MULTI-MODAL: THE RESEARCH CENTER IS ESTABLISHED

While FDOT has had some form of research program since 1916, the subject focus remained quite narrow – materials, road building, and, to a lesser extent, structures. Other divisions, such as planning and traffic operations, would sporadically sponsor studies on pertinent topics as their budgets would allow, but there was no systematic research program outside of materials.

In 1989, FDOT established the Research Center – an office dedicated to research funding and oversight. Under the leadership of Richard Long, the research activities of FDOT expanded significantly both in terms of funding and research partners. Dedicated research funding, both federal and state, has gone from under $1 million per year to over $12 million. Relationships were established with more universities, including newer institutions such as the University of South Florida, Florida International University, and Florida Atlantic University. These expanded resources were made available to all divisions within FDOT and allowed the growth of a broader, more vibrant research program.

The Traffic Engineering Research Laboratory

In the 1970s, the FDOT Traffic Engineering and Operations Office operated a traffic equipment evaluation and testing shop at a Tallahassee maintenance yard. In 1996, the small shop was transformed into the Traffic Engineering and Research Laboratory (TERL), a research and testing facility staffed jointly by FDOT staff and researchers from Florida Agriculture and Mechanical University-Florida State University (FAMU-FSU) College of Engineering. TERL was charged to develop standards, specifications, testing procedures, tools, and capabilities to evaluate and approve transportation equipment for use in Florida.

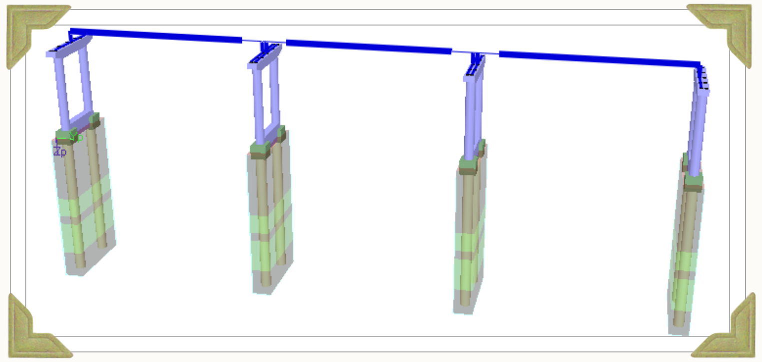
2010: A test intersection at the Traffic Engineering Research Laboratory allows researchers to try new and novel traffic engineering concepts in a controlled manner.

At TERL, researchers tackle more complex traffic engineering problems seen on Florida's streets. This includes the ever-growing fleet of new and more efficient traffic control devices, software systems, network communication equipment, dynamic message centers, and video surveillance systems. TERL has two test intersections where researchers can apply new techniques and products in a real-world simulation. These intersections have traffic signals, video and radar vehicle detection devices, and illuminated signs and are representative of both old and new FDOT roadway design standards, providing a more accurate reflection of intersections found across the state.

Together with researchers, the staff at TERL have developed improved testing tools, evaluation procedures, and equipment standards to ensure that the devices in use on Florida's roadways perform to the highest standard and communicate reliably in our increasingly connected environment.

Improving Bridge Design through Technology: FB-MultiPier

In the early 1990s, FDOT began funding a research project at the University of Florida modestly titled "Development of a Coupled Bridge Superstructure and Foundation Finite Element Code." This study laid the groundwork for the highly successful design program, FB-MultiPier. At the time, engineers used eight different pieces of software to design and analyze bridge substructures. A typical, fairly complicated design with just one configuration could take up to two weeks to design and determine accurate loads. The result of the first study, FLPIER, was a DOS-based, three-dimensional soil structure interaction analysis program, and it was a major leap forward. It could create and evaluate three to ten models per day and perform accurate analysis of design loads. Engineers could then design bridges with a much higher degree of confidence and more accurate estimates of design loading conditions. One of the first bridges designed with FLPIER resulted in an estimated savings of $2 million in construction costs.



2014: FB-MultiPier continues to be improved by FDOT-funded research. This photo shows a multiple-pier bridge model used for a demonstration of dynamic relaxation. (BDV31 977-17)

Based on the early success of FLPIER, FDOT and the University of Florida continued to collaborate to enhance FLPIER and create other sorely needed bridge design tools. The first update, FB-Pier, converted FLPIER to a Windows-based program. However, FB-Pier could not analyze loads outside of strictly bridge substructures, including mast arms, high mast lighting, sound wall foundations, retaining walls, and pile bent modeling.

As research continued to evolve, so did the software. The next release, FB-MultiPier could generate multiple piers and subsequently analyze an entire bridge simply by changing pile layout, materials, and geometric configurations.

FB-MultiPier continues to evolve, incorporating results of other FDOT research projects to improve its modeling capabilities. Recently, information gleaned from barge-bridge impact studies was used to improve the software's equations to account for potential barge strikes. Today, FB-MultiPier is a leader in bridge software and widely used in the structures engineering community.

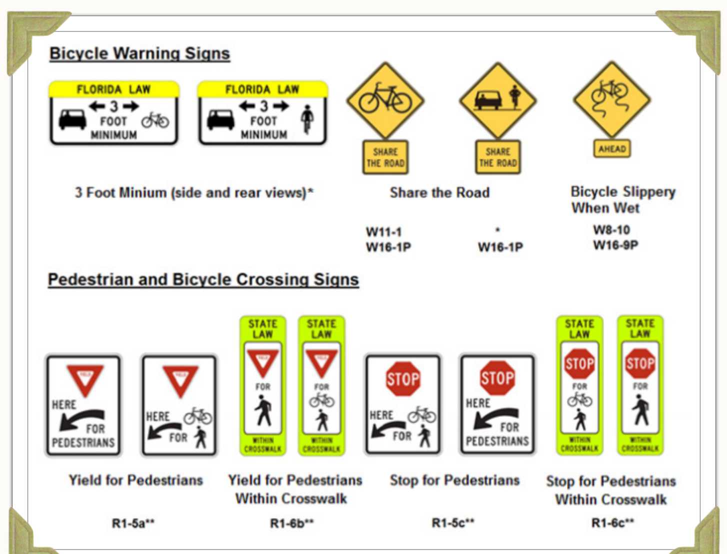
Leveraging Psychology for Safer Roads

In 1991, the FDOT Traffic Engineering and Operations Office established the Elder Road User Program to focus on the needs of drivers and pedestrians as they age. Although the aging process is highly variable from person to person, at approximately age 55 the ability to process information, remember details, and make effective judgments begins to deteriorate. The aging driver is a special concern in Florida – by 2020, one in four Florida drivers will be over 65.

The Elder Road User Program, later renamed Safe Mobility for Life, began looking for ways to improve the safety of an aging population, including drivers, pedestrians, cyclists, and transit riders. Using the Federal Highway Administration's *Highway Design Handbook for Older Drivers and Pedestrians* as a starting point, the staff turned to human factors research to determine which design changes yielded results.

Human factors, also known as functional design, is the scientific discipline concerned with the understanding of interactions between humans and other elements of a system– in this case, the roadway – in order to optimize human well-being and overall system performance. From 1991 to the present, researchers funded by FDOT have applied human factors techniques to provide recommendations to increase the safety of older road users behind the wheel, on a bicycle, crossing the street in a crosswalk, and even walking in parking lots.

While some roadway modifications, such as wider stripes and overhead street name signs were easily evaluated for improvement, other changes were more opaque. In one study, researchers compared aspects of sign and signal effectiveness for various age groups. Sign reflectivity, message sign word order, sign fluorescence, pedestrian signals in crosswalks, auditory feedback devices, and message sign letter height were evaluated for effectiveness across three age groups: 21-35 years old; 36-64 years old; and 65 years and older. The results helped FDOT determine which changes were most effective and where to focus educational materials and efforts.



2013: In a human factors research project focused on driver interaction with pedestrians and bicyclists, different types of warning signs were evaluated for legibility and recognition across age groups. (BDK83 977-15)

FDOT also brought this person-centered approach to roadway improvement to the national level. Florida engineers participated in two focus groups for the Transportation Research Board's Transportation in an Aging Society research project. Through the implementation of research-verified improvements, FDOT is working to improve the safety and preserve mobility of an aging population.

Wildlife Ecopassages

As the 1990s drew to a close, the Environmental Management Office of FDOT needed solutions to ensure the safety of some non-traditional road users: wildlife. As projects are planned, they are studied for compliance with the National Environmental Policy Act to ensure that any potential habitat and wildlife impacts of projects are considered and mitigated. FDOT also seeks to go beyond these federal requirements and address wildlife impacts in broader terms, seeking to sustain Florida's unique habitats and wildlife populations for future generations. This massive undertaking requires research and innovative ideas.

Currently, Florida has over 122,000 centerline miles of roads. Wildlife interacts with these roads. Through research and innovative thinking, FDOT has sought solutions that serve every type of road including, including our wildlife population that limit the need for road crossing and connect potentially disconnected wildlife habitats.

Alligator Alley crosses a large portion of the range of the Florida panther. As it was being upgraded in the late 1980s and early 1990s to carry Interstate 75, FDOT looked for ways to limit this hazard to both motorists and the panther population. Complete right-of-way fencing would effectively separate the already small panther population into two even smaller groups. To mitigate this risk , both fencing and underpasses were incorporated into the rebuild of Alligator Alley. No such system for large carnivores had been built in Florida previously.

A study was commissioned in 1992 to judge the effectiveness of this experimental design. Bobcat movements were tracked using radio telemetry as their migration patterns closely mimic the much less prevalent panther. The wildlife crossings themselves were also monitored by game cameras that take pictures when a beam of infrared light is broken, capturing an image of whatever caused the break. The wildlife crossings were shown to effectively prevent most highway-related mortality of panthers and other large-bodied mammals.

This management practice was then extended to other locations around the state and their effectiveness studied and modified to benefit other species as well. Wildlife underpasses, now dubbed ecopassages, were constructed on State Road 46 in Lake County and US Highway 441 across Paynes Prarie State Preserve in Alachua County.

The US 441 ecopassages included an innovative amphibian-reptile wall with a pronounced 6-inch lip commonly found in zoo serpentariums. Animals who

2007: Research into ecopassages, such as this one, demonstrated that design and maintenance practices can effectively reduce wildlife mortality rates on Florida's highways

2007: The efficacy of ecopassages, like this deer guarded intersection on US 1 on Big Pine Key, was confirmed with a number of research projects.

manage to climb the vertical wall will be turned back by the lip and be encouraged to find an easier method to cross – the ecopassages. For larger mammals, especially black bear and white-tailed deer, the landscape surrounding the ecopassages was contoured to create traffic lanes through the woods which funneled animals to the passages while still providing sufficient cover. Similar successful installations have also been constructed on Big Pine Key to protect the dwindling key deer population. In all locations, the wildlife mortality rate decreased substantially, making these heavily traveled roads safer for both animals and humans.

Environmental Stewardship: Stormwater Pollution

Stormwater is a major concern in Florida. It rains as much as 40 to 60 inches in non-hurricane years. FDOT owns or controls a significant portion of land upon which this water falls and is subject to the requirements of the Florida Department of Environmental Protection (FDEP) to mitigate any impact that FDOT facilities could have on the quality of Florida's water. FDOT-sponsored research has worked to determine how to manage stormwater and maintain Florida's environment.

When rain hits the ground and drains off as stormwater, it can collect both biological and chemical pollutants that can leach back into the aquifer, potentially compromising Florida's water supply. FDOT has worked diligently to discover and implement solutions that can reduce the pollutant load.

FDOT has been sponsoring hydrology, hydraulic and coastal engineering research since at least the 1970s and has made significant contributions to the field. In the early 2000s, FDOT funded $2 million in projects at the newly-established Stormwater Management Academy at the University of Central Florida to focus on stormwater research and discover practical solutions.

2010: The rainfall simulator at the Stormwater Academy at the University of Central Florida is the largest of its type in the world. The 1,500 gallon water tank can be emptied in different droplet arrangement over a bed of sod or soil set at various slopes to study runoff behavior.

In one FDOT project conducted at the Stormwater Academy, a team of researchers studied the amount of nitrogen that enters water bodies from roadside fertilization runoff. In addition to lab tests, the researchers used a rainfall simulator that can release up to 20 inches of rain per hour and produce the drop size and intensity of rainfall characteristic of the semitropical and northern regions. Using the simulator and lab tests, researchers examined soil compositions, slope, moisture level, and vegetation cover to determine the most likely amount of pollution runoff.

The Stormwater Academy and FDOT also partnered with the Department of Environmental Protection, the Department of Community Affairs (now the Department of Economic Opportunity) with technical assistance from the Governors Committee on the Wekiva and the St. Johns Water Management District to establish stormwater best practices to protect important watersheds statewide. In 2005, after a three-year study, the Stormwater Academy published the *Wekiva River Stormwater Management Manual of Practice,* which provides much-needed scientific knowledge regarding the spring flow of the Wekiva River springshed and the best practices to manage and preserve an important piece of Florida's environment.

FDOT's partnership with the Stormwater Academy continues to increase the knowledge of stormwater and provide solutions and answers to Florida's stakeholders.

LOOKING TO THE FUTURE

As we move further into the twenty-first century, FDOT will continue to pursue improvement through innovation in all areas of transportation. The world is becoming more and more connected, information moves faster than ever, and technologies will transform the face of transportation. The robust research program at FDOT will work to prepare Florida's people and visitors for this exciting future.

Intelligent Traffic Systems

Advanced traffic management systems use a number of intelligent transportation system (ITS) technologies to manage the vehicles on the roadways and to maximize the value and capacity of the transportation system. These ITS devices include closed-circuit television cameras, GPS antennas, microwave vehicle detectors, loop sensors built into roadways, dynamic message signs, and more. All of Florida's ITS devices are connected by fiber-optic network to Transportation Management Centers (TMCs) and managed with SunGuide software.

Use of individual ITS systems and the SunGuide software itself are largely products of FDOT research projects. FDOT first deployed ITS devices in early 2000 on portions of limited access roads in Jacksonville, Orlando, Miami, and portions of the Turnpike. Each roadway system was managed by a different software system. To enable coordination of equipment statewide, FDOT and the Michigan Department of Transportation jointly funded the development of a unified software system. The study ultimately led to the development and customization of SunGuide. Using SunGuide to aggregate and interpret data from the thousands of ITS devices on Florida's roadways, TMC operators manage incidents, dispatch assistance, and inform drivers via dynamic message signs, Florida 511, and the highway advisory radio.

2007: The Traffic Management Center at District 6 in Miami monitors the flow of traffic and responds to incidents in the most densely populated region of the state.
Source: SeeFloridaGo.com

2014: The University of Florida's Transportation Institute is using this automated vehicle to conduct important research on automation and its implications for Florida's transportation network.

Automated/Connected Vehicles

While ITS devices and function-specific sensors continue to advance and integrate, FDOT is also looking to the future and funding the necessary research for Florida's roadways to accommodate an important trend in the future of transportation: connected and autonomous vehicles. Connected vehicles communicate with everything around them – the infrastructure, ITS devices, and other connected vehicles. According to the United States Department of Transportation, 80% of avoidable collisions could be prevented with connected vehicle technology.

In 2011, FDOT, with assistance from USDOT, established a connected vehicle test bed in urban Orlando. FDOT installed vehicle awareness equipment on transit buses, trolleys, and FDOT maintenance vehicles. As part of this test, a new module was developed for SunGuide to interact with these connected vehicles. The data collected in this test bed are a valuable resource to continue to evaluate the connected vehicle technology and the ability to use that data in a meaningful, efficient way.

FDOT also is continuing research on autonomous vehicles. While connected vehicles use vehicle-to-vehicle and vehicle-to-infrastructure communication to provide real-time warnings to drivers to help avoid crashes, an autonomous vehicle uses advanced sensors and computing abilities to perceive its surroundings and steer, brake, and accelerate without input from the driver. Both connected and autonomous technologies can improve the safety and efficiency of Florida's transportation system.

FDOT has been conducting research on autonomous and connected vehicle technology for more than ten years seeking to gain a better understanding of any implications associated with planning for and integrating autonomous and connected technologies into Florida's existing infrastructure. Topics include the effects of these types of vehicles on roadways, environmental impacts, policy implications and the behavioral relationships between operator and the automated vehicle.

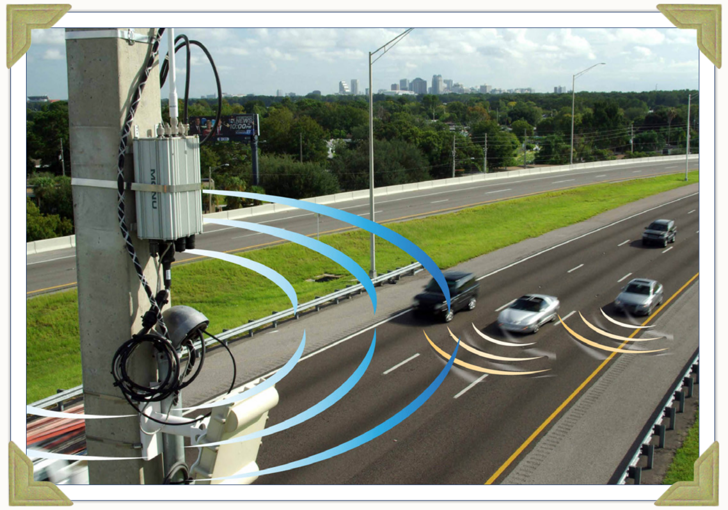
Pilot projects are being conducted across the state to gain real-world data and insight into automated and connected technologies. In Tampa, for example, FDOT vehicles as well as buses, sedans, and vans operated by local transit agencies were fitted with an advanced driver assistance system. As these vehicles are used in the course of daily business, the system will provide visual and audible warnings to the operator of an eminent forward collision, lane departure, and pedestrian/bicyclist detection. The results will be monitored closely to determine if collisions and damages are reduced and at what rate to help FDOT make recommendations for future uses.

While fully autonomous vehicles are rapidly making their ways onto our roadways, the technologies behind them (LIDAR, radar, etc.) are also being studied to determine how they can help FDOT perform its functions. For instance, a recent FDOT-funded project determined that an unmanned aerial vehicle equipped with cameras can significantly reduce the cost and increase the safety of bridge and high mast luminary inspections without compromising the integrity of the inspection. A future project is planned to determine which on-water bridge inspection needs could be satisfied by unmanned surface vehicles.

> “When automated and connected vehicles appear, Florida will be ready for them.

As technology advances, FDOT uses research to look for ways in which it can benefit both itself as an efficient and effective organization and the people of Florida as they move about the state. When automated and connected vehicles appear, Florida will be ready.

2014: Unmanned Aerial Vehicles (UAV) for bridge and high mast luminary inspection bring autonomous and automated technology to the maintenance work of FDOT. (BDV28 977-02)



2014: Connected vehicles communicate with other vehicles on the roadway as well as the infrastructure itself - including these sensors mounted on a light pole.

IN CONCLUSION

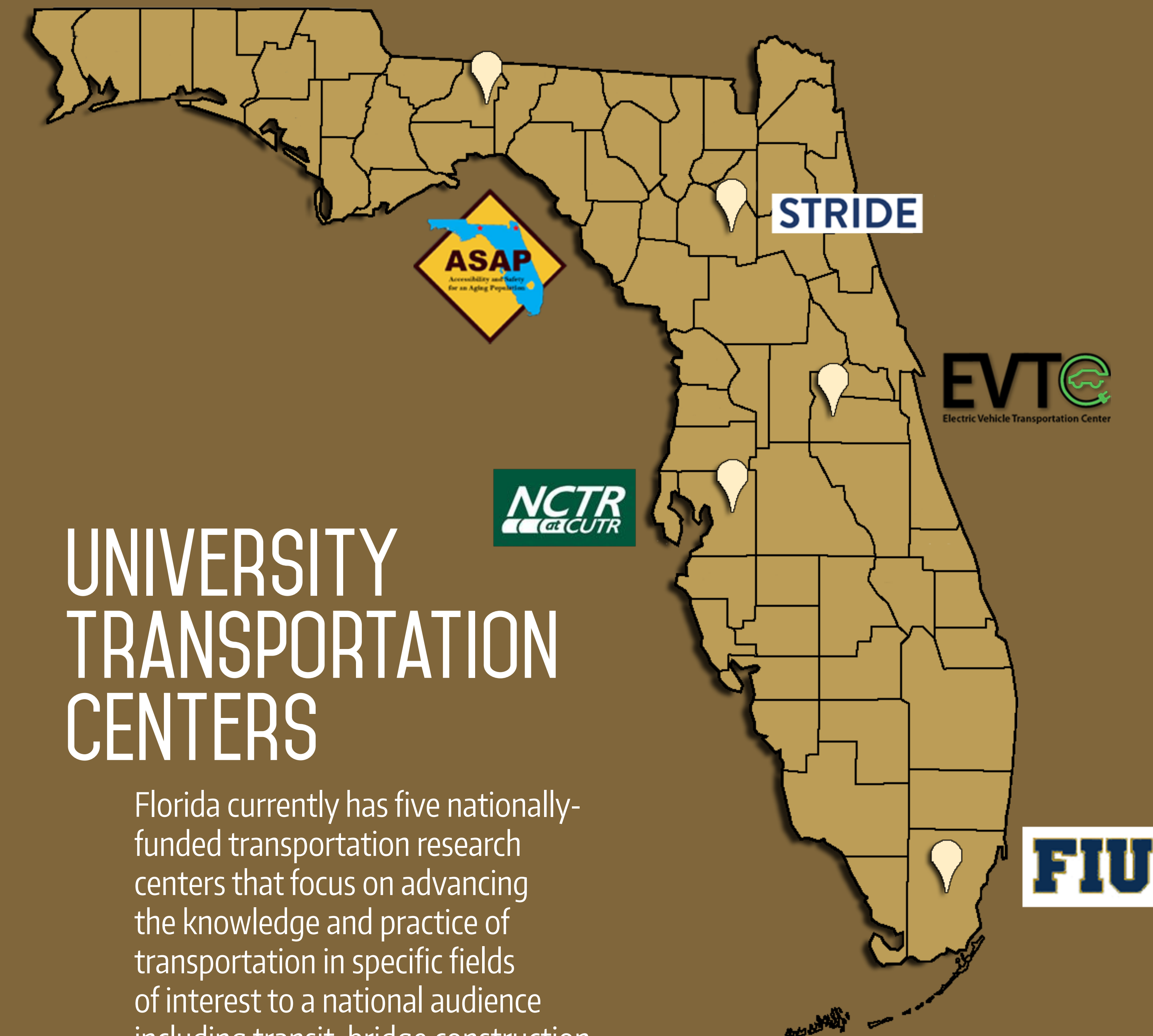
Like the state itself, FDOT has grown and changed dramatically over the last 100 years, moving from a small cadre of engineers providing assistance to the various counties in building roads to a dynamic multi-modal agency focused on providing a safe transportation system that ensures the mobility of people and goods, enhances economic prosperity, and preserves the quality of the environment and communities. As we step into the next century, the research program will continue to provide innovative solutions that answer the next group of transportation questions.

Whatever the future holds for Florida transportation -- new vehicles, fuels, materials, computing, planning -- one hundred years of progress through research have positioned FDOT to boldly step into its next century.

RESEARCH PARTNERS

Though the Research Center partners with universities and research providers outside the state, the vast majority of FDOT-funded research is conducted at both public and private Florida universities across the state.

Embry-Riddle Aeronautical University ¤ Florida Agricultural and Mechanical University ¤ Florida Atlantic University
Florida Gulf Coast University ¤ Florida Institute of Technology ¤ Florida International University
Florida State University ¤ Nova Southeastern University ¤ University of Central Florida ¤ University of Florida
University of Miami ¤ University of North Florida ¤ University of South Florida ¤ University of West Florida



UNIVERSITY TRANSPORTATION CENTERS

Florida currently has five nationally-funded transportation research centers that focus on advancing the knowledge and practice of transportation in specific fields of interest to a national audience including transit, bridge construction, aging road users and electric vehicles.

Accelerated Bridge Construction Center (FIU) ¤ Center for Accessibility and Safety for an Aging Population (FAMU-FSU)
Electric Vehicle Transportation Center (UCF) ¤ National Center for Transit Research (USF)
Southeastern Transportation Research, Innovation, Development and Education Center (UF) – *funded until Jan 2016*

This edition owes its existence to the generous folks of the Florida Department of Transportation, past and present, who shared their knowledge and experiences with me. Thank you for letting me tell your stories.

- Jessica VanDenBogaert

FURTHER READING

The history of FDOT research appears in many different places. The following is an abbreviated list of sources. For more information, please contact Jessica VanDenBogaert at 850.414.4631.

Biennial Reports of the State Road Department and the Florida Department of Transportation, 1915-1970

Highway Skid Resistance; a Symposium. Philadelphia: American Society for Testing and Materials, 1969.

Historic Highway Bridges of Florida. Tallahassee: Florida Department of Transportation, 2004.

Kendrick, Baynard. *Florida Trails to Turnpikes, 1914-1964*. Gainesville: University of Florida Press, 1964.

Marder, Walter S. "Pleasing the Eye: Brick Paving and the Dixie Highway in the Sunshine State." in *Looking Beyond the Highway: Dixie Roads and Culture*, edited by Claudette Stager and Martha Carver. Knoxville: University of Tennessee Press, 2006.

Nasser, George D. *Reflections on the Beginnings of Prestressed Concrete*. Chicago: Prestressed Concrete Institute, 1981.

NCHRP at 50 Years. Washington, DC: Transportation Research Board, 2012.

NCHRP Synthesis 398: Cathodic Protection for Life Extension of Existing Reinforced Concrete Bridge Elements. Washington, DC: Transportation Research Board, 2009.

Research Showcase. Tallahassee: Florida Department of Transportation, 2012-2015

Research Reports

BD545-34 Improvements in Design Scour Depth Prediction

Project Manager: Rick Renna
Principal Investigator: D. Max Sheppard

BDV31 977-17 Development of FB-MultiPier Dynamic Vessel-Collision Analysis Models, Phase 2

Project Manager: Sam Fallaha
Principal Investigator: Jae Chung

BDK83 977-15 Aging Road User, Bicyclist and Pedestrian Safety: Human Factors Studies Phase 3 Effective Bicycling Signs and Preventing Left-Turn Crashes

Project Manager: Gail Holley
Principal Investigator: Walter Boot

BD521-02 Wekiva River Stormwater Management Manual of Practice

Project Manager: Rick Renna
Principal Investigator: Marty Wanelista

FALL 2015

Centennial FDOT 1915 ★ 2015

Research Center

605 Suwannee Street, MS 30 Tallahassee, FL 32399-0450

(850) 414-4615

http://www.dot.state.fl.us/research-center/