NONDESTRUCTIVE PAVEMENT EVALUATION OF STEWART INTERNATIONAL AIRPORT'S RUNWAY 9-27

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ABSTRACT

Knowledge of the existing structure and condition is critical to developing a reliable, cost-effective pavement restoration design. Airside pavements present a challenge in this regard, due to the limited time windows afforded for pavement evaluation and the critical nature of ensuring their structural and functional integrity. A nondestructive testing survey, incorporating various NDT methods, was utilized to meet this challenge on Runway 9-27 at Stewart International Airport in upstate New York. This runway was programmed to receive improvements, including converting the existing typical cross-slope to a crown section. During low volume hours an integrated testing vehicle equipped with Ground Penetrating Radar (GPR), a high-speed Inertial Profiler, and a high-resolution video camera was deployed to measure pavement thickness and smoothness in addition to capturing video and complemented by a Heavy Weight Deflectometer (HWD) to back-calculate layer moduli along testing lines at various transverse offsets.

Analyzed GPR data was compared to ground truth core data provided by the owner (PANYNJ) at several locations, and the thickness results were found to correlate fairly well. In addition to producing the asphalt thickness, survey data along each of the test lines was utilized to produce the elevation profile of the top and bottom of the asphalt layer. This information was used by the owner to model the AC layer using *AutoCAD Civil 3D.* The GPR data yielded an explanation for anomalous cores ranging up to 43 inches thick and avoided the need for more extensive coring. Ultimately, the NDT survey was used to segment the runway along the tested offsets, allowing for a comprehensive and reliable design assessment and construction quantity estimates. Additionally, the data was presented for visualization through a software interface that enables the coordinated simultaneous viewing of video and pavement data.

INTRODUCTION

Knowledge of the existing structure and condition is critical to developing a reliable, cost-effective pavement restoration design. Airside pavements present a challenge in collecting this data, due to the limited time windows afforded for pavement evaluation and the critical nature of ensuring their structural and functional integrity. Nondestructive pavement evaluations make it possible to collect this information in an efficient and cost-effective manner. Nondestructive test (NDT) techniques also provide the added benefit of increased testing coverage, thereby increasing the likelihood of identifying weak spots and/or needs for improvement. An NDT program was carried out on Runway 9-27 at Stewart International Airport (SWF) in October of 2011 to better understand the existing pavement conditions while developing the restoration plans for that runway.

OVERVIEW OF THE PROJECT

Runway 9-27 is approximately 150 ft. wide (including an approximately 30 ft. wide shoulder on each side) and 12,000 ft. long and contains an asphalt surface throughout its length. Stewart Airport receives 47,666 operations annually and falls under Airplane Design Group D-VI. At the time of the project the runway maintained its original linear cross-slope cross-section. However, an objective of the restoration work was to perform a crown conversion to meet current standards. Pavement core results from a previous testing program indicated that the asphalt concrete (AC) layer thickness ranges from 11 to 43 inches. This variability generated a great deal of concern over the reliability of the resulting pavement design, particularly the expected pavement life at the edge of the runway if the centerline profile could not be raised.

With this in mind, the Port Authority of New York and New Jersey (PANYNJ) contracted for nondestructive testing and evaluation services (NDT/E) on the Runway 9-27 pavement at Stewart New York International Airport, which is held under their jurisdiction. The project site is located in the towns of Newburgh and New Windsor, New York. The intent of the NDT/E work on this project was to provide a comprehensive yet cost-effective assessment of the existing structure and condition of the Runway 9-27 pavement.

The pavement evaluation involved a review of existing documents as well as NDT pavement testing in the field. The field testing included video collection, Ground Penetrating Radar (GPR) testing, high-speed Inertial Profiler testing, and Heavy Weight Deflectometer (HWD) testing. Locations were referenced in terms of stationing and offsets from the existing centerline, as provided by PANYNJ. When referencing offsets, "right" and "left" refer to right and left of the runway centerline/baseline in the direction of increasing stationing (from 9 end to 27 end).

NONDESTRUCTIVE TESTING PROGRAM

The nondestructive testing program on Runway 9-27 involved the following tasks:

<u>Reviewed existing documents</u>

This included a review of the available As-Built plans, core information, and soil boring information for the project area. The pertinent core information was compiled and summarized in tabular format, including pavement layer thicknesses and core locations. The core information also included a core photo log. Figure 1 below shows an example of the photos included. Figure 2 below shows a portion of the core table produced. Figures 3 and 4 show the core location plan provided, that includes the baseline stationing and runway layout.

<u>Collected video</u>

High-resolution video data was collected, processed and compressed for PANYNJ's use and incorporation in the video/data integration software, which is discussed in more detail below. Video was collected utilizing a high-definition 2 mp video system simultaneously with GPR testing using the vehicle shown in Figure 5 below. The pictured testing vehicle integrates GPR testing, Inertial Profiler testing, and video collection for one-pass collection of these data types. Figure 6 below shows the post-processed high-resolution video collected at a 10 ft. right offset.

<u>Performed Ground Penetrating Radar (GPR) testing and analysis</u>

GPR testing utilizing a 2 GHz air-launched antenna and a 900 MHz ground-coupled antenna was conducted along three offsets – 10 ft., 20 ft., and 69 ft. – from the centerline on each side of the runway as well as along the centerline of both shoulders. The offsets coincide with the offsets of HWD testing (which are prescribed in FAA AC150/5370-11A [1]), as pavement thickness information from the GPR was used to analyze the HWD data. The GPR testing was also performed in accordance with the guidelines in FAA AC 150/5370-11A [1] and ASTM D 4748-06 [2]. The GPR data was used to determine the variation in thickness of the AC layer utilizing the GSSI GPR analysis software *Radan*. The variations in estimated AC layer thickness for the runway for the left and right offsets and the left and right shoulders were plotted separately. Figure 7 below shows the plot for the right offsets. The AC layer thicknesses from the cores are superimposed in these figures. In addition, PANYNJ provided elevation data at one-foot intervals along each of the approximate test lines. This data along with the AC layer thickness was used to calculate the elevation of the bottom of the AC layer along the runway at the tested offsets. The elevations of the top and bottom of the AC layer for the runway were then plotted. Figure 8 below shows one such plot for the 10 ft. right offset.

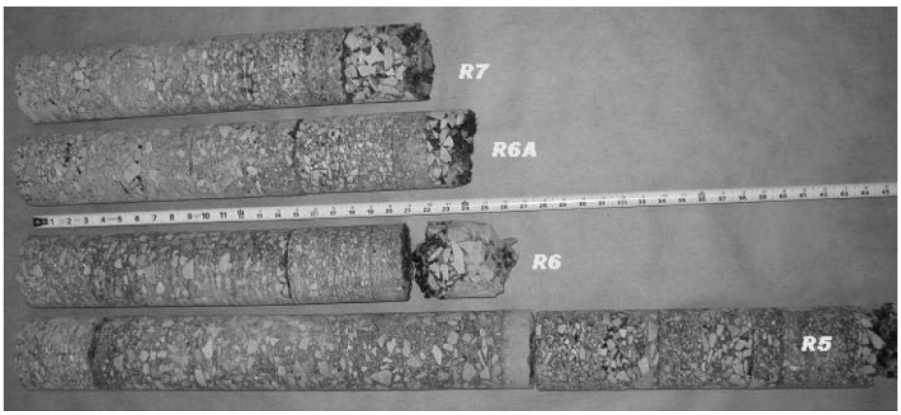

Figure 1. Example of Core Photo Log

Summary of Core Data Provided by PANYNJ

Core #	Offset (ft. L/R)	Station	Total AC Thickness (in.)	Total PCC Thickness (in.)	Plant Mix Thickness (in.)	Penetrated Stone Thickness (in.)
R1	20L	13+60	16.00	---	---	---
S1	RS	13+60	4.50	---	---	---
S2	LS	13+60	4.00	---	---	---
R2	20R	44+75	15.25	---	---	---
S4	LS	51+60	5.00	---	---	---
R3	20L	56+70	11.00	8.00	---	---
S5	RS	56+70	4.75	---	---	---
S6	LS	56+70	5.50	---	---	---
R4	20R	76+50	16.75	7.00	---	---
S8	LS	76+50	4.25	---	---	---
R5	20R	88+75	43.00	---	3.00	4.00

Figure 2. Image of Core Data Summary Table

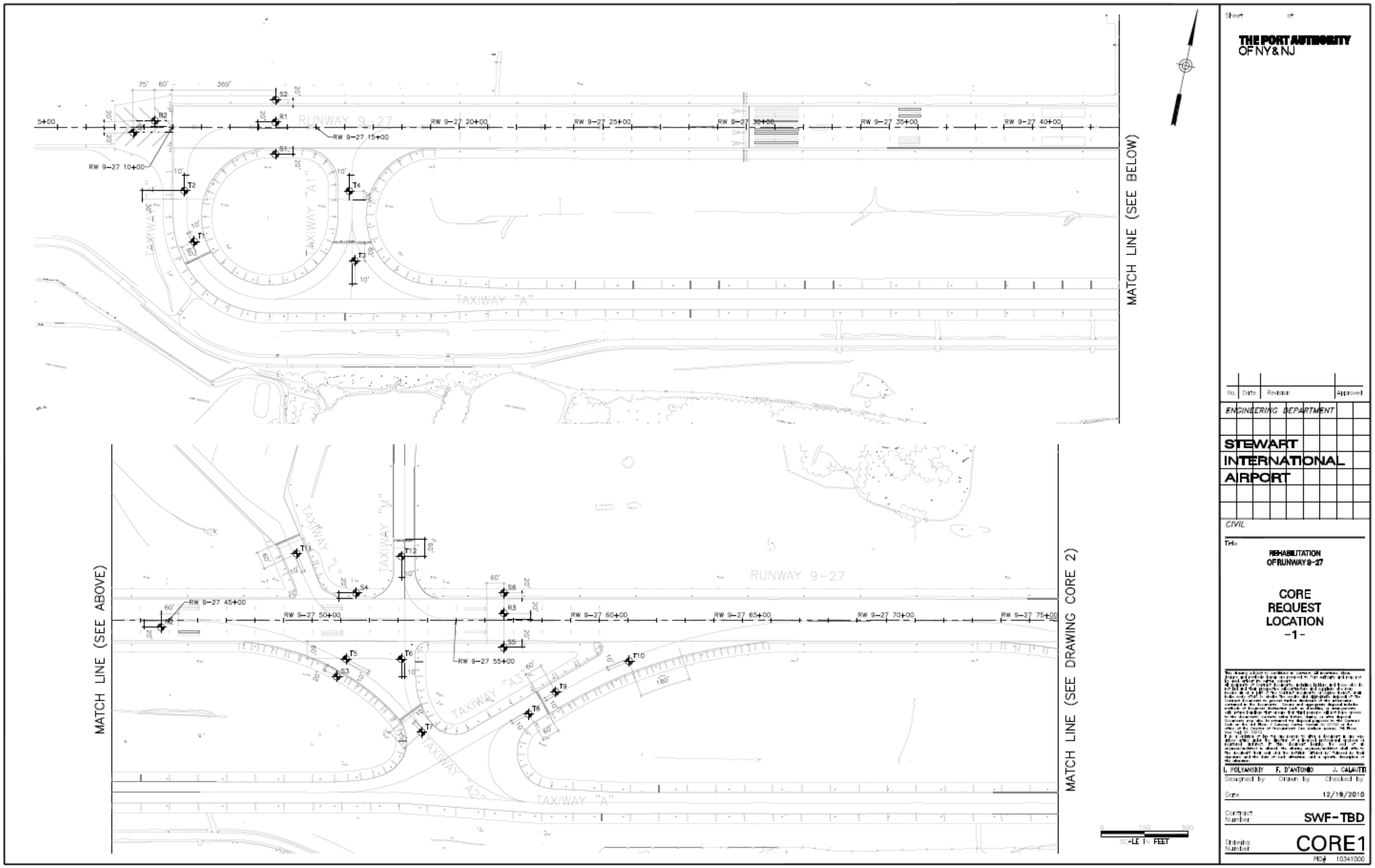

Figure 3. Core Location Plan (sheet 1)

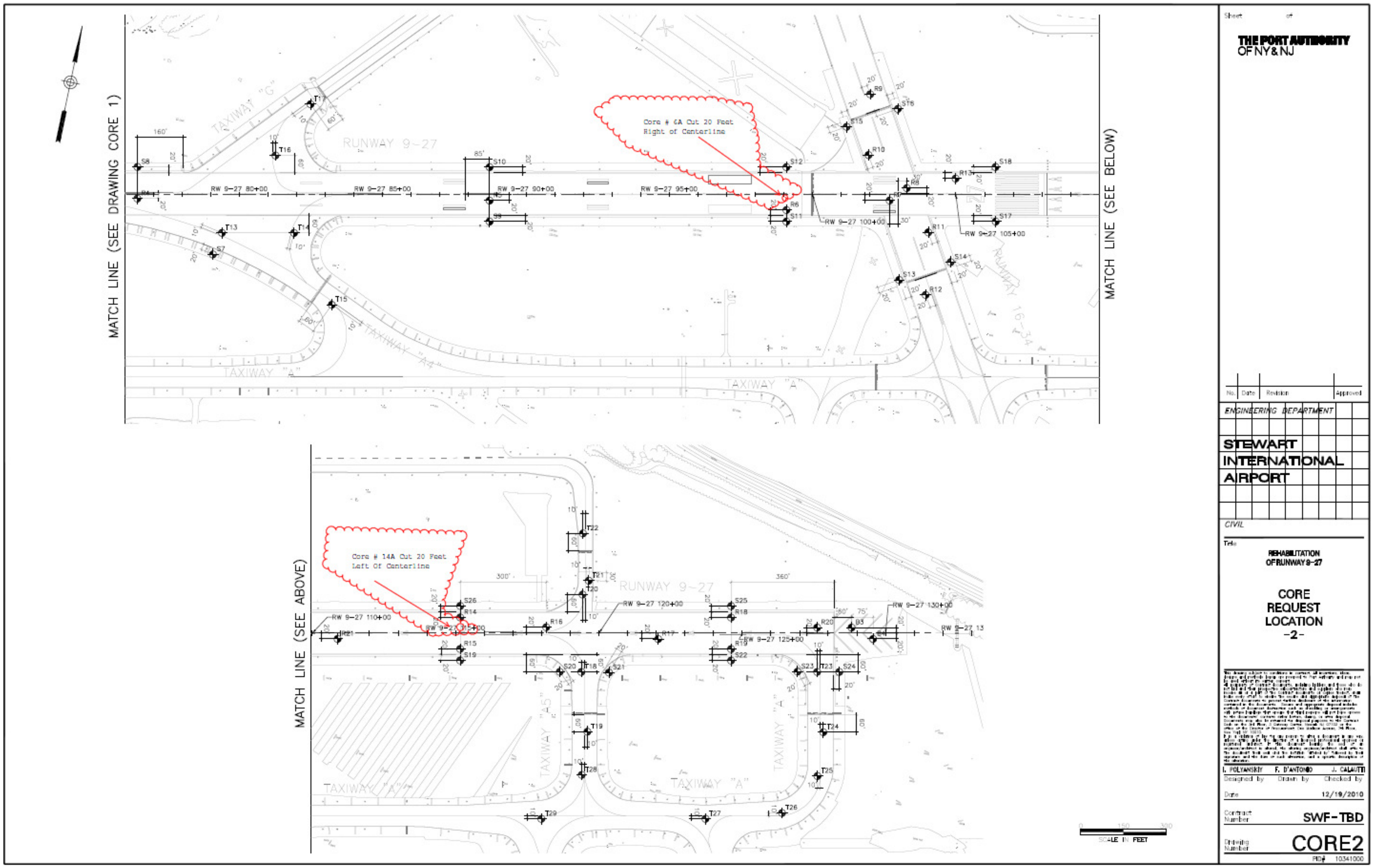

Figure 4. Core Location Plan (sheet 2)

Figure 5. Integrated Testing Vehicle

Figure 6. High-resolution Video

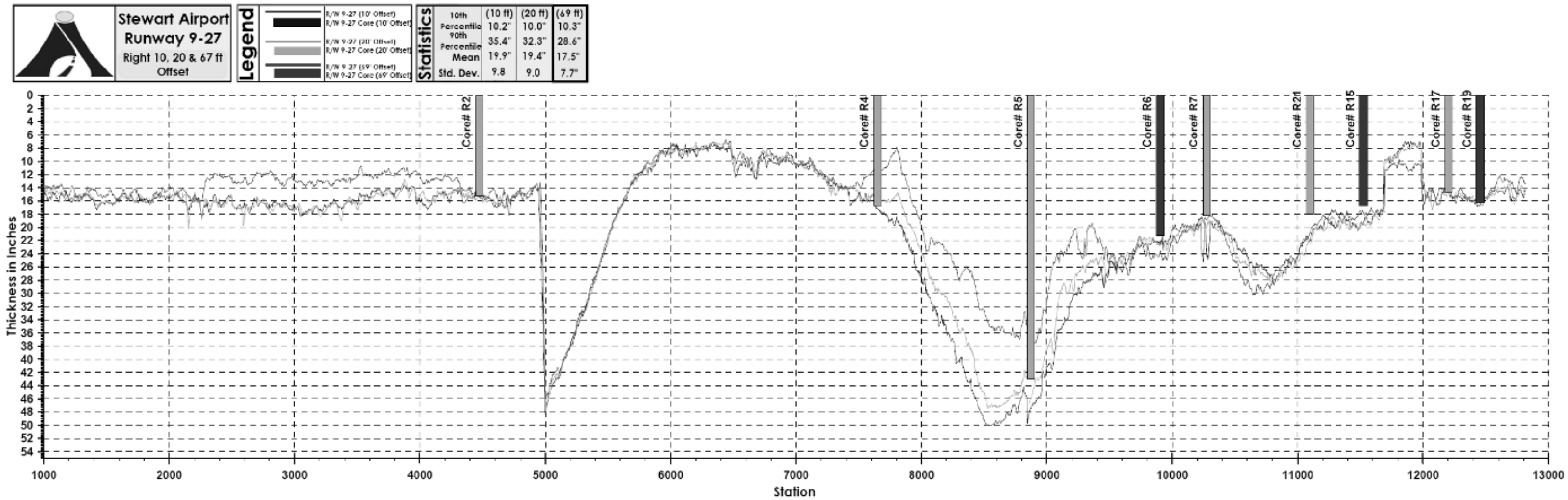

Figure 2. Variation in AC Thickness for Stewart Airport, Runway 9-27, Right 10, 20 & 69 ft. Offsets, Based on GPR Data

Figure 7. Plot of AC Layer Variation along right offsets

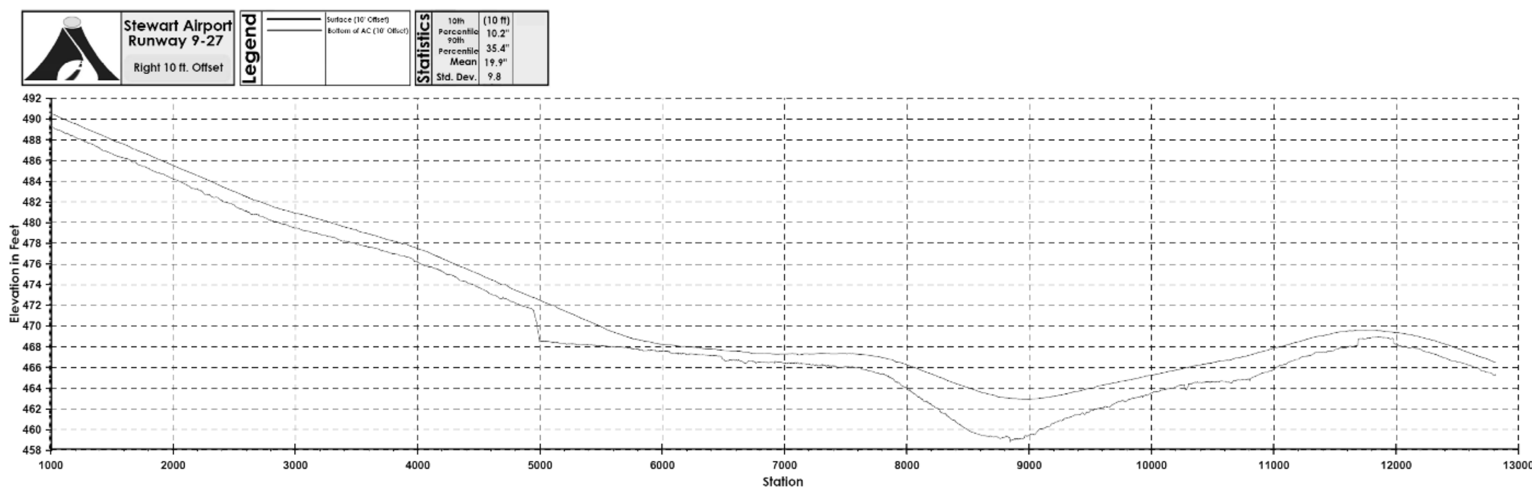

Figure 6. Variation in AC Surface & Bottom Elevation for Stewart Airport, Runway 9-27, Right 10 ft. Offset, Based on GPR Data

Figure 8. Plot of AC Top & Bottom Elevations along 10 ft. right offset

Conducted Inertial Profiler testing

A full-size Inertial Profiler was utilized to perform a high-speed ride quality survey of Runway 9-27. The data was collected along the centerline of the runway and at a 17.5 ft. offset on each side of the centerline, resulting in three test lines, based on the designation of the airport falling under Airplane Design Group D-VI. The testing was performed based on the guidelines in FAA AC 150/5380-9 [3]. Note that the profiler testing was conducted under separate runs from the GPR/video runs, as the FAA guidelines prescribed different testing offsets in this case. The profile data was used to evaluate the ride quality of the runway in terms of the International Roughness Index (IRI), simulated Profile Index (PI), and simulated Rolling-Straight Edge (RSE). The FHWA software *ProVAL* was utilized to perform this analysis.

Performed Heavy Weight Deflectometer (HWD) testing and analysis

HWD testing was conducted in accordance with FAA AC 150/5370-11A [1], ASTM D4694-96(03) [4], and ASTM D4695-03 [5] utilizing the KUAB HWD machine shown in Figure 9 below. This testing was carried out approximately every 100 ft. along 10 ft. left and right offsets from centerline, every 150 ft. along 20 ft. left and right offsets, and every 300 ft. along 69 ft. left and right offsets in flexible (i.e., AC only) pavement areas. “Center” testing in composite (i.e., AC over Portland cement concrete (PCC)) pavement areas was conducted every 100 ft. along 10 ft. left and right offsets from centerline, every 100 ft. along 30 ft. left and right offsets, and every 200 ft. along 69 ft. left and right offsets. Composite pavement joint testing was not conducted on this project, due to a lack of visible reflection cracking, which prevented location of the joints.

Figure 9. KUAB HWD Machine at Stewart International Airport

The HWD testing, which involved applying three load drops of 18.5, 24.0 and 31.0 kips and one seating drop of 24.0 kips at each test location, was performed to allow for determination of the various pavement layer moduli, including (where applicable) the AC, PCC, base, subbase, and subgrade layers. FAA AC 150/5370-11A [1] and ASTM D 5858-96(03) [6] were followed for the backcalculation of the pavement parameters. TTI's backcalculation software program *Modulus* was used to perform the backcalculation.

Prepared Video/Data Integration software package

Along with conventional reporting, the NDT/E results for Runway 9-27 were presented for visualization in a video/data integration software developed by Advanced Infrastructure Design, Inc., the pavement engineering firm that carried out the NDT/E study. This software enables the simultaneous viewing of video of a pavement and the data corresponding to that pavement as the video runs along the project length. Figure 10 below shows an example configuration of the software for the 10 ft. right offset.

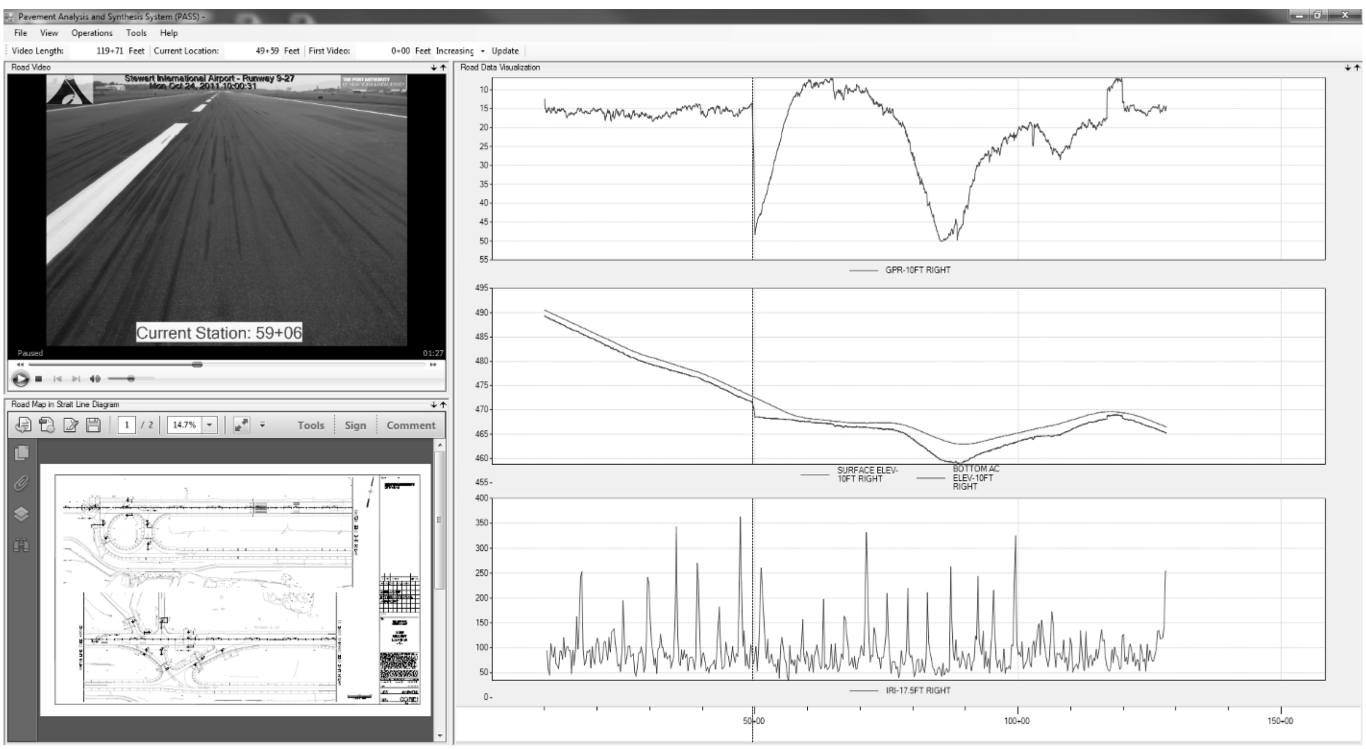

Figure 10. Visualization Software

OVERALL PAVEMENT CONDITION ASSESSMENT

In order to facilitate sectionalization of the runway pavement for design, the GPR and HWD test results were summarized in Table 1 below. In this table Runway 9-27 has been divided into sections (by offset) identified to have fairly uniform pavement structure and condition. The average results for each section are reported in the table. The following is a summary of some of the findings from the GPR and HWD testing:

- The sections from ~Sta. 10+00 to 50+00 and from ~Sta. 83+00 to 117+00 are comprised of flexible pavement, while the sections from ~Sta. 50+00 to 83+00 and from ~Sta. 117+00 to 128+18 consist of composite pavement.

- The flexible pavement areas consist of approximately 15-20 in. of AC, while the composite pavement areas are comprised of 8-14 in. of AC. Some sections were found to have highly variable AC layer thicknesses, varying from approximately 16 to 48 in. in some cases. These large, variable thicknesses may be the result of utilizing the AC layer to achieve an acceptable vertical profile for the runway during past construction. As a result of these findings, PANYNJ investigated the construction history and discovered that ~Sta. 50+00, which shows a steep change in AC thickness, corresponds to the previous end of the runway prior to an extension project.

- In general, excluding the areas where the taxiways meet the runway, the shoulders consist of flexible pavement with an approximately 2-6 in. AC layer. The right shoulder from ~Sta. 102+00 to 128+18 is an exception, consisting of composite pavement with 4-11 in. of AC over 6-7 in. PCC slabs.

- The PCC slab thickness varies by section within the runway limits. The slabs are approximately 8 in. thick from ~Sta. 50+00 to 83+00, approximately 10 in. thick from ~Sta. 117+00 to 120+00, and approximately 6 in. thick from ~Sta. 120+00 to 128+18.

- Considering the HWD test results together with the photos provided for the cores, it was concluded that the AC layer was generally in good condition throughout the runway, while the PCC slabs in the composite pavement areas were in fair condition. The backcalculated AC modulus generally ranged from 600 to 1000 ksi, while the backcalculated PCC modulus generally ranged from 2500 to 4500 ksi.

- Base and subbase types and thicknesses were assumed based on the As-Built information provided. The core information suggests that a stiff base layer exists from ~Sta. 83+00 to 117+00, consisting of 3-4 in. of “Plant Mix” (apparently a fine mix AC) over 3-4 in. of “Penetrated Stone” (apparently an asphalt-coated Macadam).

- The FWD backcalculated subgrade modulus generally ranges from 4500 to 7500 psi, translating to a correlated California Bearing Ration (CBR) of 3 to 5%. The soil boring information provided indicates that the subgrade consists of silt with varying amounts of sand and gravel. The boring logs also reveal the presence of fragmented bedrock (shale) at a depth generally ranging from 6 to 8 feet.

In order to further facilitate sectionalization of the runway pavement for design, the ride quality test results were summarized in Table 2 below. The average results for each pavement section are reported in the table. The following is a summary of some of the findings from the ride quality testing:

Table 1.
Summary of Average Pavement Evaluation (Structure & Moduli) Results by Section for Runway 9-27

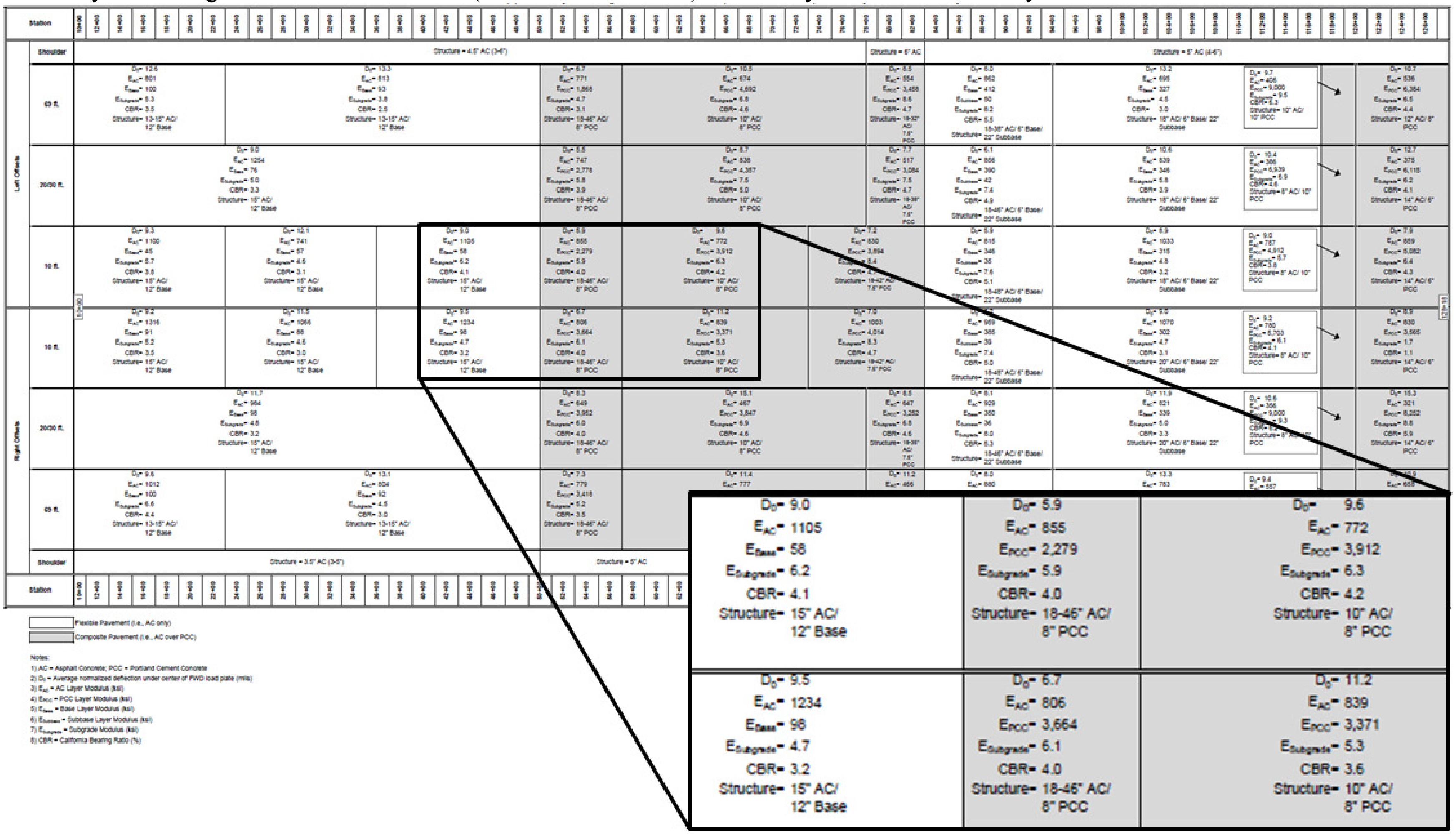

Table 2.
Summary of Average Pavement Evaluation (Ride Quality) Results by Section for Runway 9-27

Station: 10+00, 12+00, 14+00, 16+00, 18+00, 20+00, 22+00, 24+00, 26+00, 28+00, 30+00, 32+00, 34+00, 36+00, 38+00, 40+00, 42+00, 44+00, 46+00, 48+00, 50+00, 52+00, 54+00, 56+00, 58+00, 60+00, 62+00, 64+00, 66+00, 68+00, 70+00, 72+00, 74+00, 76+00, 78+00, 80+00, 82+00, 84+00, 86+00, 88+00, 90+00, 92+00, 94+00, 96+00, 98+00, 100+00, 102+00, 104+00, 106+00, 108+00, 110+00, 112+00, 114+00, 116+00, 118+00, 120+00, 122+00, 124+00, 126+00

Offsets											
17.5 ft. Left	IRI= 108 PI= 15.1 RSE= 1.81	IRI= 91 PI= 12.2 RSE= 2.04		IRI= 79 PI= 1.3 RSE= 1.57	IRI= 88 PI= 8.9 RSE= 1.36	IRI= 96 PI= 14.0 RSE= 1.74	IRI= 96 PI= 12.6 RSE= 2.26	IRI= 94 PI= 9.2 RSE= 1.42	IRI= 89 PI= 6.3 RSE= 0.0	→	IRI= 86 PI= 10.0 RSE= 1.70
Centerline (10+00 … 128+18)	IRI= 172 PI= 32.1 RSE= 7.63		IRI= 108 RSE= 15.1 RSE= 2.32	IRI= 100 PI= 3.5 RSE= 1.87	IRI= 93 PI= 9.9 RSE= 1.46	IRI= 106 PI= 15.5 RSE= 3.94	IRI= 87 PI= 9.8 RSE= 1.46	IRI= 97 PI= 10.0 RSE= 1.44	IRI= 85 PI= 7.5 RSE= 0.26	→	IRI= 102 PI= 13.6 RSE= 2.13
17.5 ft. Right	IRI= 99 PI= 11.0 RSE= 1.45	IRI= 98 PI= 14.0 RSE= 2.03		IRI= 96 PI= 3.8 RSE= 1.43	IRI= 90 PI= 9.4 RSE= 1.81	IRI= 85 PI= 10.5 RSE= 2.19	IRI= 85 PI= 9.1 RSE= 0.98	IRI= 94 PI= 10.6 RSE= 1.73	IRI= 77 PI= 4.5 RSE= 0.0	→	IRI= 97 PI= 8.4 RSE= 1.21

Flexible Pavement (i.e., AC only)
Composite Pavement (i.e., AC over PCC)

Notes:
1) AC = Asphalt Concrete; PCC = Portland Cement Concrete
2) IRI = International Roughness Index (inches/mile), Average for Both Wheel Paths
3) PI = Profile Index (inches/mile), Average for Both Wheel Paths
4) RSE = Rolling Straight Edge (Percent Defective)

- In general, both Profile Index and Rolling-Straight Edge percent defective are considered to be good indicators of localized roughness (i.e., short wavelength features such as bumps and dips). A large amount of localized roughness is only indicated in one section - the centerline from ~Sta. 10+00 to 31+00. Based on a review of the video and observations in the field, there is a concentration of runway lighting along the centerline within this area that was unavoidable during testing. It is believed that this is the source of the roughness being reported.

- In general, International Roughness Index is considered to be a good indicator of overall roughness (i.e., wavelengths up to approximately 300 ft.) by the highway community. While IRI is not a standard parameter for airfield pavements, this analysis was performed for comparative purposes. The section mentioned above along the centerline from ~Sta. 10+00 to 31+00 also resulted in a high IRI value of 172 in./mi., which on an interstate highway pavement would be considered “Deficient”. The remainder of the runway generally resulted in IRI values between 80 and 110, which would be considered “Good” to “Fair” for an interstate highway pavement.

APPLICATION OF NDT DATA TO DESIGN

As can be seen from the project presented, a great deal of detailed, useful information can be obtained from conducting a nondestructive pavement evaluation. In the case of Stewart Airport, the PANYNJ found that the elevation profile of the bottom of the AC layer obtained from the GPR testing was particularly useful. It allowed them to model the bottom surface of the AC layer in *AutoCAD Civil 3D* and evaluate the resulting AC layer thicknesses for their design in the cut areas in the outer portions of the runway. This detailed modeling also provides the ability to calculate more accurate construction quantities.

In general, having access to detailed pavement structure and condition data allows for the identification of unique conditions such as changes in layer thicknesses, lower quality or degraded pavement materials, areas of softer subgrade, or segments with a rougher existing profile. Having knowledge of the existence and extent of such conditions provides the opportunity to create a more reliable and customized design when needed, as opposed to a one treatment fits all approach. In addition to identifying unique conditions a nondestructive pavement evaluation provides all of the pavement structure related information required to carry out a design in accordance with FAA AC 150/5320-6E [7] utilizing FAA’s *FAARFIELD* software.

REFERENCES

1. Federal Aviation Administration, Office of Airport Safety and Standards, “Use of Nondestructive Testing in the Evaluation of Airport Pavements,” Advisory Circular AC 150/5370-11A, 2004.
2. ASTM Standard D 4748-06, “Standard Test Method for Determining the Thickness of Bound Pavement Layers Using Short-Pulse Radar,” ASTM International, West Conshohocken, PA, 2006.

3. Federal Aviation Administration, Office of Airport Safety and Standards, “Guidelines and Procedures for Measuring Airfield Pavement Roughness,” Advisory Circular AC 150/5380-9, 2009.
4. ASTM Standard D 4694-96, “Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device,” ASTM International, West Conshohocken, PA, 2003.
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