Determination of an Optimum Speed for the Simultaneous Collection of Pavement Imaging, Ground Penetrating Radar, and Inertial Profiling Nondestructive Airport Pavement Data in a Moving Vehicle

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Abstract
In November 2014, representatives from the Federal Aviation Administration (FAA) and support contractor, SRA International, collected pavement data on an airport runway in southern New Jersey, USA. Runway 1 – 19 is asphalt, approximately 5000 ft. (1524 m) long x 150 ft. (45.7 m) wide. Data collection included 2D and 3D pavement imaging, Ground Penetrating Radar (GPR), and pavement profiling and roughness technologies. The purpose was to acquire data from all three technologies simultaneously at different speeds and determine if there is an optimum speed for future data collection that would accommodate the three data sets. Preliminary analysis of the 2D and 3D pavement imaging indicates satisfactory resolution at various speeds. The analysis of longitudinal profiling and Ground Penetrating Radar at varying speeds is ongoing. The data for all three technologies was collected using the FAA Nondestructive Testing (NDT) Van, a Ford E-350 commercial cutaway vehicle with a delivered shipping weight of 5201 lbs. (2359 kg) that has been customized as a mobile NDT platform.

Keywords
Pavement imaging, ground penetrating radar, airport pavement profiling

1. INTRODUCTION

Previous data collection efforts at remote airports indicated that data from different technologies requires different travel speeds for the NDT Van. Typically, mobile nondestructive airport pavement testing vehicles are outfitted by vendors that supply the data acquisition equipment – both hardware and software - including the vehicle. The FAA purchased the vehicle separately and then outfitted as required. The FAA procedure for collecting NDT airport pavement data is to travel longitudinally on the runway working left to right (for WWD in the East to West direction) from one shoulder to the other in 9ft. (2.74 m) parallel increments for image stitching. This paper will present the challenges of the simultaneous data collection and the potential future use of this data. See Figure 1.
2. Pavement Imaging Background and Concerns

The Waylink imaging system has a 3D divider resolution parameter that can be set to a value between 1 and 6. The 3D divider parameter represents a number of pulses from the DMI (Distance Measuring Instrument). Every time the set numbers of pulses are received from the DMI, the Waylink control chassis will send a pulse to the camera which triggers the camera to save a line of data. When the 3D divider is set to a value of 1, every pulse from the DMI is sent to the camera and the best resolution is achieved with a NDT Van travel speed of <10 mph (16.1 km/hr.). When a value of 6 is used, good resolution can be achieved with a NDT Van travel speed of 60 mph (96.6 km/hr.). The resolution progressively lowers from 1 to 6, and the NDT Van travel speed progressively increases. In harmony with manufacturer recommendations, the FAA has typically used a value of 1 or 4 for the 3D divider at an image acquisition speed of 15 mph (24.1 km/hr.). Therefore, when collecting data sets simultaneously the limiting speed was 15 mph (24.1 km/hr.) due to the pavement imaging. Part of this testing is to learn how significant the resolution difference is between these two settings at varying speeds. The FAA wanted to determine if the data could be collected at a higher speed to allow for shorter times on the airport pavement and if the image data could be collected closer to the optimum travel speed for the inertial profiling and Ground Penetrating Radar - 30-35 mph (48.2 – 56.3 km/hr.).

The consensus for the FAA inertial profiler has been to acquire data at a constant speed between 30-35 mph (48.2 – 56.3 km/hr.). Part of this testing included investigating new minimum and maximum data acquisition speed limit of the systems. The FAA inertial profiling system is comprised of a Selcom laser, a Datron distance measuring instrument, and a two-axis accelerometer.
The GPR manufacture (GSSI) recommends not exceeding 35 mph (56.3 km/hr.) during data acquisition. This limit was further investigated during testing. The FAA GPR data acquisition system includes an air coupled antenna collecting data at 2GHz and a ground coupled antenna collecting data at 400MHz with published depth ranges from 0 – 30 in (0.76 m) and 0 – 12 ft. (3.66 m), respectively.

2.1 Test Plan

The FAA team prepared a test plan as follows. Collect surface images, longitudinal profile data, and GPR data simultaneously on the 5,000 ft. (1524 m) long asphalt pavement surface of runway 1/19 at WWD. This would be done at 3 longitudinal profile line locations for a total of 8 different data acquisition speeds. The locations of the 3 longitudinal profile lines were the centerline and ±5 ft. (1.52m) offsets on either side of the centerline for the full length of the runway. The target data acquisition speeds to be tested were <15, 15-a, 15-b, 20, 25, 30, 35, 40, and 60 mph (24.1, 32.2, 40.2, 48.2, 56.3, 64.4, and 96.6 km/hr.). 15-a mph and 15-b mph represent separate data collection done at the same speed but with different pavement imaging resolution parameters.

The Waylink imaging system mounted on the FAA NDT van was to be run with a 3D divider value of 1 for the speeds of <15 and 15-a mph. The remaining speeds (15-b, 20, 25, 30, 35, 40, and 60 mph) (24.1, 32.2, 40.2, 48.2, 56.3, 64.4, and 96.6 km/hr.) would utilize a 3D divider value of 4.

The FAA inertial profiler’s 5th wheel which collects pavement groove data at slow speeds was to be used for the measurement speeds of <15 and 15-a mph. The 5th wheel would be removed for the remaining speeds (15-b, 20, 25, 30, 35, 40, and 60 mph) (24.1, 32.2, 40.2, 48.2, 56.3, 64.4, and 96.6 km/hr.).

Regular data acquisition of the air-coupled/ground-coupled GPR was to be used for all speeds.

2.2 Data Collection

On November 4, 2014, the FAA team traveled to WWD to collect the data as per the testing plan above. There were two changes to the testing plan: (1) runway availability allowed for use of only 2,400 ft. (731.5 m) of runway 1/19 and (2) the FAA team decided to add a speed of 50 mph (80.5 km/hr.) to the testing procedure, for a total of 9 different data acquisition travel speeds (<15, 15-a, 15-b, 20, 25, 30, 35, 40, 50 and 60 mph) (24.1, 32.2, 40.2, 48.2, 56.3, 64.4, 80.5, and 96.6 km/hr.).

2.3 Imaging System Results

There is no discernable difference in 2D image quality at any data acquisition speed. Analyzing the 3D data shows that there is a noticeable progressive decrease in the quality of 3D rendering at data acquisition speeds greater than 30 mph (48.2 km/hr.). The decrease in quality of the 3D image is typically represented by noise or spikes in the 3D image. At data acquisition speeds less than 30 mph (48.2 km/hr.) there is no significant difference in quality in 3D image resolution.
2.4 Inertial Profiler Results

**Speed:** consistent speeds, which would be defined as between accelerations and decelerations over the whole profile data, to minimize possible errors during the conversion of acceleration gains were observed with 35mph (56.3 km/hr.) or lower measurement speeds based on Datron data. The FAA developed profile program, “Profile32”, was used to plot speed and elevation data for comparison purposes.

**Elevation:** Longer wavelengths that effect roughness index computations were observed with 30mph (48.2 km/hr.) or lower speeds based on the Datron distance measuring instrument.

2.5 Air-Coupled/Ground-Coupled GPR Results

GPR data was collected using a 6.5 dielectric constant and a Gain = 12. In accordance with the GSSI literature, a beeping sound (alarm) was generated when the data acquisition speeds exceeded 35 mph (56.3 km/hr.). Further data analysis was conducted to confirm the speed limit and data quality using GSSI provided Radan 7 data processing software. However, no significant discrepancies were observed between different levels of speeds except “active electricity”.

3. CONCLUSIONS

Analysis of data acquired at Cape May, NJ (WWD) clearly identifies maximum data acquisition speeds for all three NDT devices installed on the FAA NDT van. Based on image data from the Waylink imaging system, a recommendation can be made that speeds should not exceed 25 mph (40.2 km/hr.) with a 3D divider of 4 during data acquisition. Based on the speed and inertial profile data, it can be recommended to acquire data at 30 mph (48.2 km/hr.) or less using the FAA inertial profiler. The GPR system behavior (alarming sound) and data support a recommendation that speeds should not exceed 35 mph (56.3 km/hr.) during data collection. Therefore, a recommendation of 25 mph (40.2 km/hr.) was made for the optimum data acquisition travel speed using the equipment installed on the FAA NDT van. This data acquisition travel speed meets the needs of all devices without sacrificing data reliability and usability while allowing for more efficient data collection in the field. This alternate speed of 25 mph (40.2 km/hr.) will be attempted and evaluated during airport pavement data acquisition in the summer of 2015. The collection of nondestructive airport pavement testing data directly supports two initiatives for the FAA. The first is to acquire pavement data of 100% of a pavement branch such as a runway or taxiway instead of sampling and the second is to determine if this data can be used to ascertain the remaining life, both functionally and structurally, of airport pavement.
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