FAA's Instrumentation Project at John F. Kennedy International Airport to Study Load and Environment Induced Responses in Concrete Pavements

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ABSTRACT: Pavement instrumentation data helps in a better understanding of pavement system responses under varied climatic and operating conditions, and for the validation and calibration of analytical response prediction models. Improved pavement design and evaluation tools will conserve airport development funds and reduce the downtime of airfield pavements for construction and maintenance activities. The success of the instrumentation project at Runway 34R-16L at Denver International Airport (DIA) encouraged the Federal Aviation Administration to initiate a project in 2008 titled "Field Instrumentation and Testing". Under this project, Taxiway-Z at JFK International Airport, NY, USA, was instrumented with 48 strain gages, 10 pressure gages, and temperature gages. The objective is to study the curling effects of concrete slabs, measure total strain and load induced strain in slabs under multi-gear aircraft such as A-380, B-777, B-747, and measure load induced strain at an offset under the same aircraft to study top-down cracking. The pavement cross section consists of 20-inch (50.8-cm) concrete slab over a 4-inch (10.2-cm) plant mix Macadam and a 6-inch (15.2-cm) dense graded aggregate base. A remotely controlled state of the art data acquisition system coupled with a camera collects static and dynamic data. The system is self-sufficient in power (supplied by solar panels and rechargeable batteries). This paper presents the details of the pavement instrumentation project, strain gage data collected during curing of concrete, and pavement response data under multi-gear heavy aircraft, and our findings to date.

KEY WORDS: Pavement instrumentation, concrete, strain gages, pressure cells, aircraft.

1 INTRODUCTION

Pavement instrumentation data helps in a better understanding of pavement system responses and can also be used for the validation/calibration of analytical response prediction models. The Federal Aviation Administration (FAA) has initiated field instrumentation and testing project, the main objectives of which are better understanding of long-term pavement behavior in the field under varied climatic and operating conditions and improved characterization of paving materials. Improved pavement design and evaluation tools will conserve airport development funds and reduce the downtime of airfield pavements for construction and maintenance activities. The specific objectives are:

- Evaluate the effects of environment on pavement performance;
- Determine thermal gradients within asphalt and concrete layers;

- Determine the effects of material properties and variability on pavement response and performance;
- Determine the effects of construction quality on pavement response and performance;
- Determine the effects of specific design features on pavement response and performance; and
- Develop improved material characterization through in-situ and laboratory testing at new construction projects and, when available, subgrade testing for rehabilitation projects.

Data collected includes climatic data (pavement & air temperatures), pavement response data (strains, deflections), material samples for laboratory testing, in-situ test data (non-destructive tests, vane shear, dynamic cone penetrometer, etc.), and heavy weight deflectometer tests. Current instrumentation projects include Denver International Airport, Denver, CO, Hartsfield-Jackson International Airport, Atlanta, GA, LaGuardia International Airport, NY, JFK International Airport, NY, and Newark Liberty International Airport, Newark, NJ.

FAA, in collaboration with Port Authority of New York and New Jersey (PANYNJ), initiated a pavement instrumentation project in 2010. Four slabs of Taxiway-Z at John F. Kennedy International Airport (JFK) leading to runway 13R-31L were instrumented with concrete strain gages, pressure cells, and temperature gages. The following sections of this paper present the research objectives, runway 13R-31L reconstruction project, details of instrumentation installed in pavement, data acquisition system, and preliminary sensor data collected.

2 OBJECTIVES

An important parameter missing in FAARFIELD is the effect of curling on pavement thickness design. Severe curling can cause premature cracking and incur high maintenance costs. Currently, the curling of slabs is controlled by limiting the ratio of slab size and thickness. The primary objectives of this project are:

- Study curling in slabs (wet-freeze climatic region).
- Measure total strain and load induced strain in slabs under multi-gear aircraft such as A-380, B-777, B-747, etc.
- Measure load induced strain at an offset under multi-gear aircraft such as A-380, B-777, B-747, etc.

This instrumentation project will provide valuable slab curling data for updating structural models in FAARFIELD.

3 RUNWAY 13R-31L RECONSTRUCTION PROJECT

JFK International Airport is one of the busiest airports in the USA and handles approximately 48 million passengers annually (Zummo and Marsano, 2010). The Bay Runway (13R-31L) is 14,572 feet (4,442 m) long and handles almost one-third of this traffic. Based on life cycle cost analysis and discussions with airlines on construction delays, the Portland cement concrete (PCC) option was selected to rebuild 13R-31L. Construction of a 10,925-foot (3,330 m) long and 200-foot (61 m) wide portion of runway started on March 1, 2010 and was completed in four months. The runway reopened on June 28, 2010. The remaining construction of 3,647 feet (1,112 m) of the runway was completed in two phases.

Figure 1 shows the aerial view of Runway 13R-31L and Taxiway-Z. The pavement thickness design was performed using FAA AC 5320-6E (FAA, 2009) and FAARFIELD for a design life of 40 years. The final thickness design for the runway pavement was 18-inch (45.7 cm) thick PCC slabs on milled hot mix asphalt (HMA) material and 20-inch (50.8 cm) thick PCC slabs on open-graded HMA base for concrete taxiways. Runway and taxiway pavement cross sections are shown in Figure 2.

Figure 1: Runway 13R-31L Reconstruction Project at JFK International Airport, New York, NY.

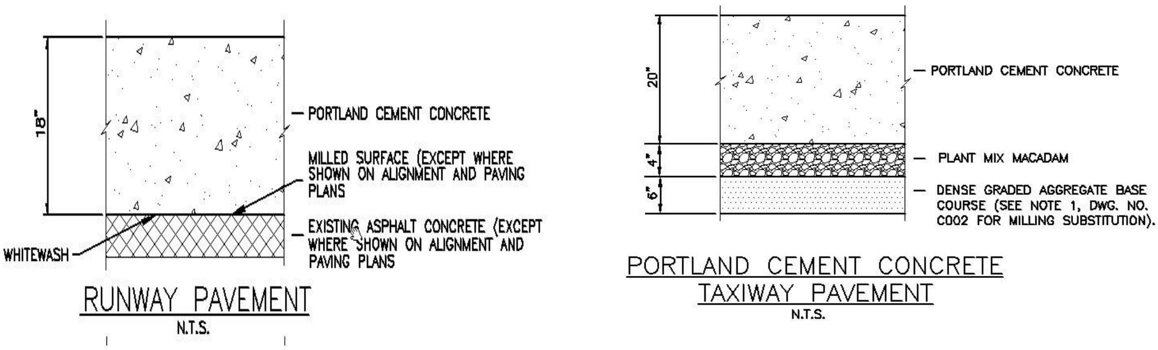


Figure 2: Runway and taxiway pavement cross sections. (1 inch = 2.54 cm)

PCC for runway and taxiways was placed using a slip-form paver. Additional details about the project can be found elsewhere (PANYNJ, 2010).

4 PAVEMENT INSTRUMENTATION LAYOUT IN TAXIWAY-Z

The FAA, in cooperation with PANYNJ, decided to install sensors in four slabs of Taxiway-Z. Installation of 40 H-bar concrete strain gages, eight Geokon strain gages, ten pressure cells, and three temperature gages was planned. Landing gear geometry of A-380 and

B-777 were considered during the development of the sensor layout plan. To study the top-down cracking in PCC pavements, it is necessary to collect surface strain gage data at various offsets along the transverse joints. The purpose of this is to investigate relative magnitudes and distributions of strains for different positions of multiple-wheel gears. Although it is not possible to place a gage in the tension zone at the top of the slab (due to the action of the augers and vibrators during placement with slip-form pavers), simultaneous readings from the gages at mid-slab and bottom of the slab can be used to estimate the load-induced strain at the top of the slab. The locations of strain gages were chosen to yield information about load-induced stresses at possible critical locations that may lead to top-down cracking, in particular for the A380. This involved placing strain gages along transverse joints at various offsets from the gear path. As an example, gages were placed along the joint of slabs that would be expected to receive loads from two gears simultaneously. To fulfill the objectives stated above, a sensor layout plan was developed as shown in Figure 3.

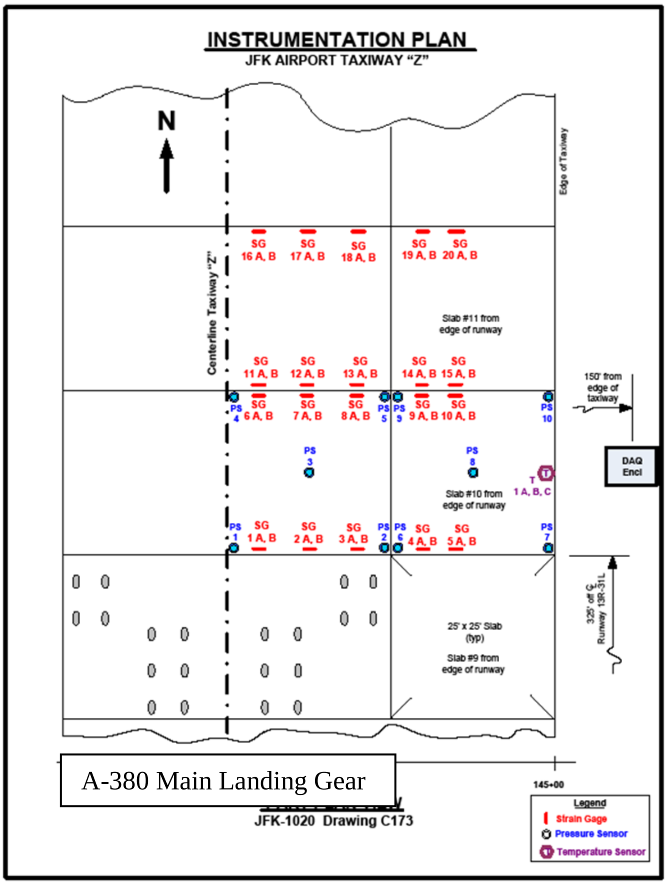
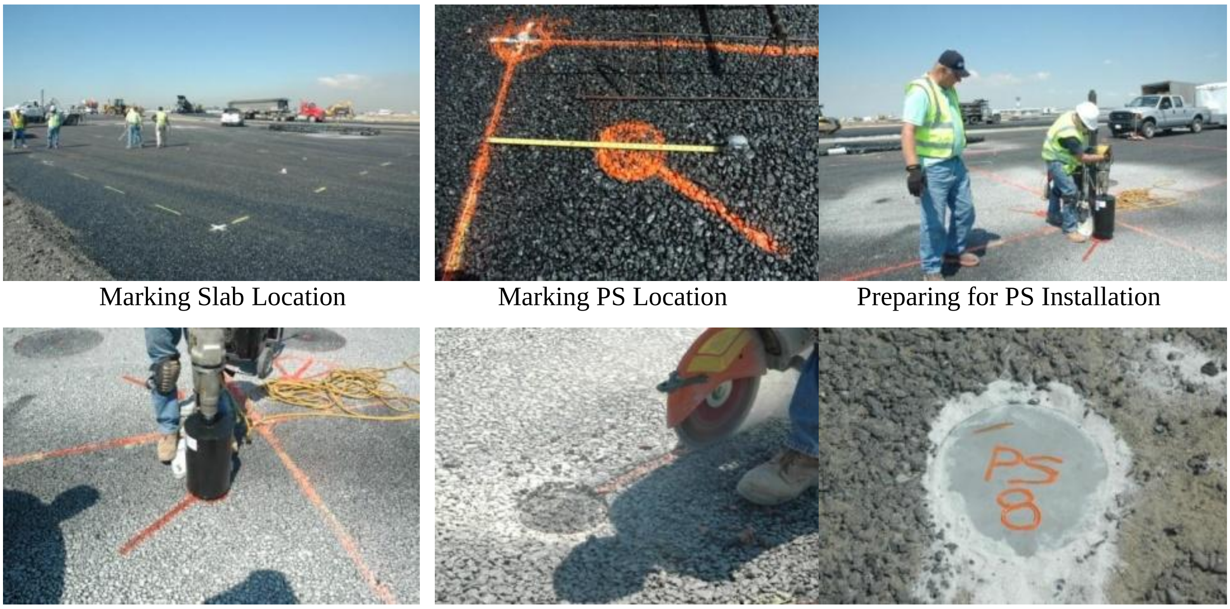


Figure 3: Sensor layout for Taxiway-Z pavement instrumentation project.

5 INSTRUMENTATION INSTALLATION

The instrumentation installation started on August 19, 2010 and was completed on August 26, 2010. The pressure cells were placed flush with the surface of plant mix macadam at locations shown in Figure 3. PS-7 and PS-10 were not installed due to construction related issues. Figure 4 shows the pressure cell (PS) installation in plant mix macadam. The PSs were manufactured by Geokon, Inc. The type T thermocouples were fabricated by Omega Engineering.



Marking Slab Location | Marking PS Location | Preparing for PS Installation

Preparing for PS Installation | Preparing for PS Installation | Installed PS

Figure 4: Installation of PS in Taxiway-Z pavement instrumentation project.

The PCC strain gages were manufactured by CTL and Geokon, Inc. Forty-eight strain gages were installed at the bottom of PCC slabs and at mid-depth to measure concrete strains. Figure 5 shows the installation of concrete strain gages (CSG) and thermocouples. Three thermocouples were installed in the bottom half of the concrete slab.

Marking CSG Locations | Marked CSG Locations | CSG Installed

CSGs Installed Across Joint | Ready for Concrete Placement | Hand Placement of PCC on gages

Placement of PCC | Slip-Form Paver | Thermocouple Installed

Figure 5: Installation of CSG and Thermocouple in Taxiway-Z pavement instrumentation project.

The cables from the instrumentation were laid in kerf cuts and brought into 12-inch (30.5 cm) light cans installed flush with the plant mix macadam base and were routed (through conduits) to a hand hole located 150 feet (45.7 m) away from the edge of the taxiway. Figure 6 shows the installation of light cans and conduits for routing cables to the hand hole.

Light Can Installation | Placing Concrete Around Light Cans | Installed Light Can for Routing Cables Through Conduits

Incoming Cables into Light Cans | Conduits Connecting Light Cans to the Hand Hole | Pulling Instrumentation Cables into the Hand Hole

Figure 6: Routing Instrumentation Cables from PCC Slabs to a Hand Hole Located 150 feet (45.7 m) from Taxiway-Z Edge.

6 DATA ACQUISITION SYSTEM

The instrumentation installation was completed on August 26, 2010. Since the construction project was completed in phases, the concrete pad for the data acquisition system (DAS) was not placed until November 2010. In order to collect initial concrete strain and temperature data, a temporary data logger was used to collect data from limited strain gages (Figure 7). The data was collected for 40 hours after the placement of concrete.

Figure 7: Installation of Data Logger to Collect Initial Instrumentation Data.

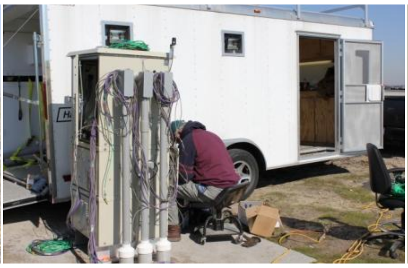
The DAS at JFK utilizes a HBM Inc. eDAQ and was installed in April, 2011. The system provides for 48 strain gage channels, 16 high voltage channels for use with Geokon pressure cells, and 8 channels dedicated to thermocouples. This unit provides the ability to acquire data both statically and dynamically from the individual sensors. This system is remotely controlled via the internet with cell communication. Static data is acquired hourly for five seconds at a 5 Hz. rate. The collected data is downloaded to the FAA William J. Hughes Technical Center, located at the Atlantic City International Airport, New Jersey, on a routine basis. Dynamic data can be selectively acquired with the video observation provided by a network camera positioned to view the approach to the test slabs. Dynamic data is sampled at a rate of 200 Hz. Power to the system is provided by a 24 volt battery bank whose charge is maintained by two solar panels. Figure 8 shows the installation of DAS.

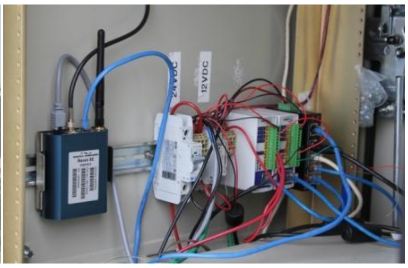

PCC Pad for DAS

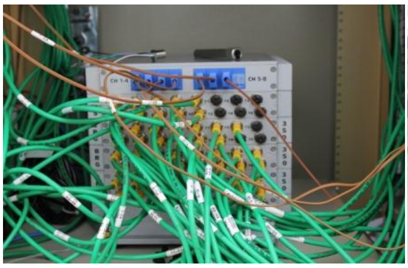

DAS Cabinet Installation


Mounting Cabinet on Frangible Couplings


Installation of Solar Panels


Connecting Sensor Cable


Communication Equipment and Control Relays


eDAQ DAS


Ventilation in DAS Cabinet


Network Camera on Cabinet

Figure 8: Installation of Data Acquisition System.

The DAS is located very close to Jamaica Bay as shown in Figure 1. Adequate ventilation was provided to keep the cabinet environment dry and at reasonable temperature. At airports, protecting the electronic equipment installed from lightning strikes is very critical. PANYNJ expertise in this field was utilized to provide lightning protection.

Figure 9 shows the installed DAS cabinet and solar panels.

Figure 9: FAA Data Acquisition System at Taxiway-Z Pavement Instrumentation Project.

7 INITIAL DATA

The instrumentation installation was completed on August 26, 2010 and a temporary data logger was used to collect initial data from selected strain gages and thermocouples. The data was collected for 40 hours after the placement of concrete. Figure 10 shows the temperature developed within the concrete slab during hydration of concrete. Temperature measurements are made at depths of 10, 15, and 19 inches (25.4, 38.1, and 48.3 cm) from the slab surface.

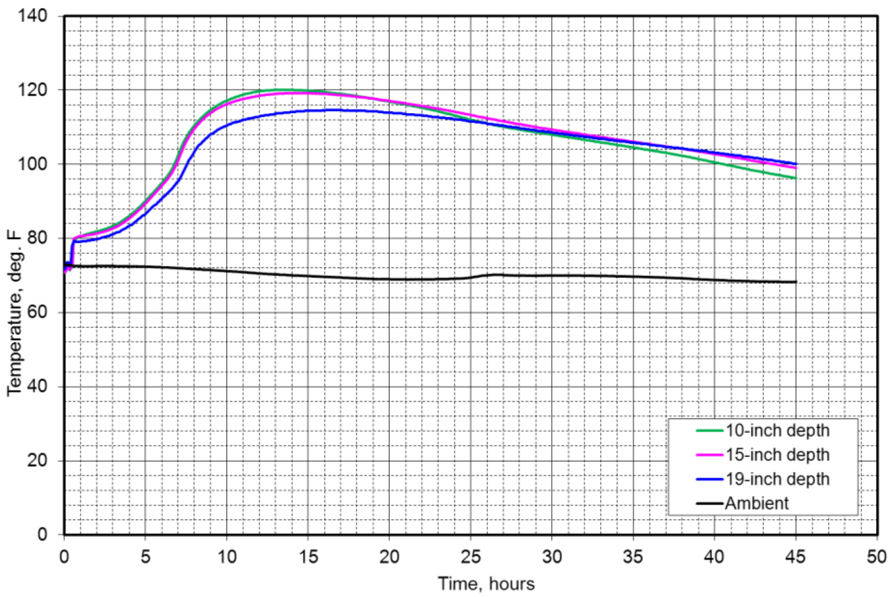


Figure 10: Temperature data collected during initial age of concrete (1 inch = 2.54 cm).

The PCC slab achieves a maximum temperature of 120˚F (49˚C) 12 hours after concrete placement. Monitoring of early age concrete temperatures is important since higher temperatures during curing have been shown to be detrimental to concrete performance (Schindler, 2002). Figures 11 and 12 show early age data from strain gages placed at the bottom and the middle of the slabs respectively (negative strain value is compressive). In general, higher absolute strains (compressive strains) were recorded at slab bottom compared to the strains at slab mid-depth.

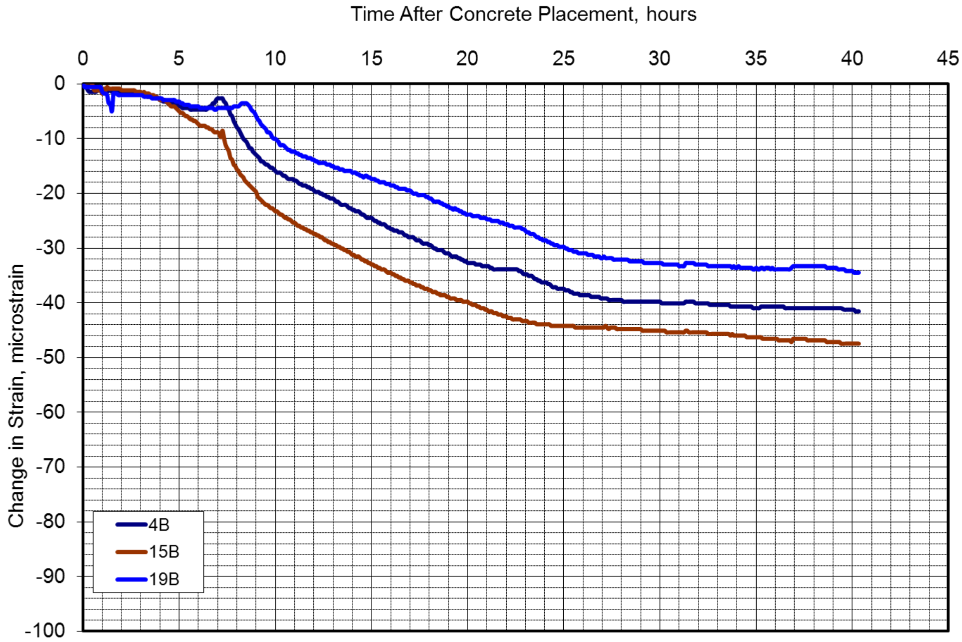


Figure 11: Early age concrete strains at bottom of the slab.

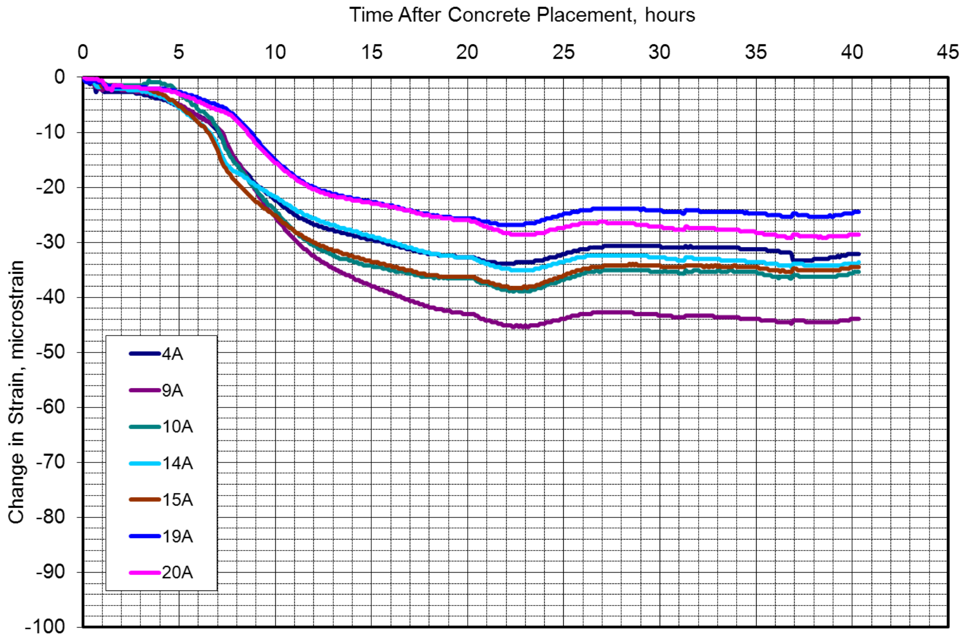


Figure 12: Early age concrete strains at mid-depth of the slab.

8 DYNAMIC DATA

A network camera mounted on the DAS cabinet (Figures 8 & 9) can be used to monitor aircraft approaching instrumented slabs and the DAS can be remotely triggered to collect dynamic data under the aircraft. The camera is also capable of taking a picture of the aircraft under which pavement responses were recorded. Figure 13 shows a typical strain gage response (located at the bottom of slab) under a Boeing-777 aircraft. In this case, the 6-wheel landing gear travels directly above the gage location. Three peaks show the response under each axle. Note that the numerical values on the vertical axis represent raw readings and the differences between them represent changes in strain. Peak values listed in Figure 13 are the change in strain, referenced to the left offset.

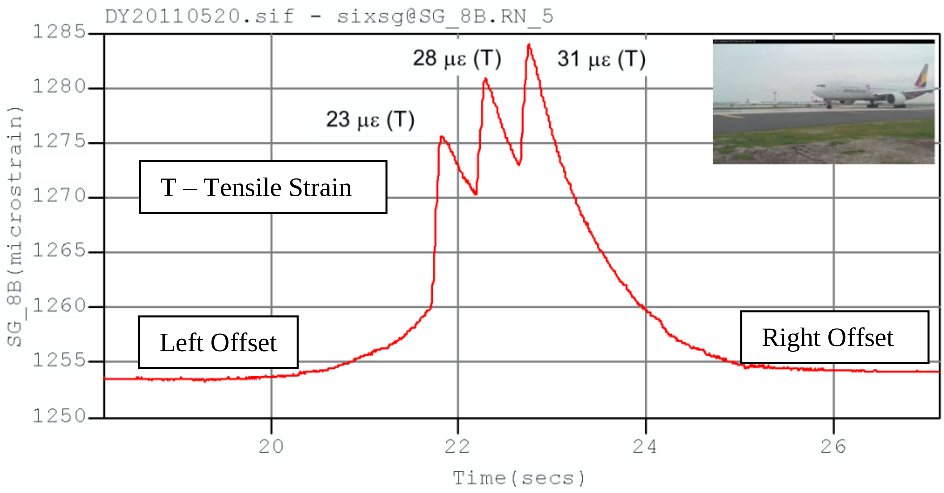


Figure 13: A typical strain gage response located at the bottom of the slab.

The FAA will continue to collect static and dynamic data. A database is currently under preparation and will be populated with the static and dynamic data. Future database will have dynamic responses associated with aircraft images for ready identification of the loads. This database will be made available to researchers for analyses.

9 CONCLUSIONS

FAA instrumented four concrete slabs at Taxiway-Z at JFK International airport to study the response of pavement under combined effect of environmental conditions and aircraft loading. The data collected from this project and other instrumentation projects located in various airports in different geographical locations (with different climates) will assist FAA in studying the curling behavior of concrete pavements and provide guidance for consideration in the pavement thickness design procedure.

10 ACKNOWLEDGMENTS/DISCLAIMER

The work described in this paper was supported by the FAA Airport Technology R&D Branch, Dr. Satish K. Agrawal, Manager. Special thanks are due to PANYNJ staff (Scott Murrell, Guy Zummo, Jason Laeterno, Bala Balakrishnan, Trevor Knot, George Guillaume, Joe Paternostro, and Emmanuel Dominique) and SRA International, Inc. staff (Matthew

Willson, Henry Fermin, Bob Debarth, Durgesh Gupta, and Josh Davis) for their contributions to this research. The contents of the paper reflect the views of the authors, who are responsible for the facts and accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the FAA. The paper does not constitute a standard, specification, or regulation.

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