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CONSTRUCTION METHODOLOGY FOR STRAIN GAGE INSTALLATION IN AIRPORT PAVEMENTS

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Installing strain gages in a pavement can give useful information on pavement distress before visible marks appear on the pavement surface. The installation of sensors at existing and busy airports comes at a price, with a very short construction window, because of the need for least disruption to air traffic owing to the expensive concessions paid by airlines almost a year in advance. As such, a proposed project on a runway at Kahului airport, Maui, Hawaii could only be granted three six-hour nights, from 11 pm to 5 am, while Honolulu airport executed a project on a taxiway that has a 7-day window, on which this article will focus. Among the many constraints – both for construction and airport safety – is the requirement that concrete attain 5000-psi strength before the taxiway is reopened to air traffic. This means that the major work of concreting on the taxiway must be completed before the end of the 4th day of the construction window. Thus, scheduling must be done in 15-minute slots. In addition, precision is key, and high productivity is required. This article describes the construction method behind this unique project.

Keywords: Delamination, Neutral axis, Milling, Data Acquisition Cabinet, Slippage, Airplane stress, Asphalt.

1 INTRODUCTION

Pavement distresses at airports are expensive to repair. Moreover, the longer a distress goes unchecked, the worse its effect is. Whereas, design improvements have potential in pavement management, normal distresses cannot be eliminated, perhaps only mitigated. With this in mind, a real-time study is underway to monitor distresses in a taxiway.

Installing early detection sensors to measure delamination is an involved task: the pavement needs to be cordoned off, the surface must be milled, sensors installed, and a trench dug to take the wires from the sensors off the runway to a data acquisition center, resting on a concrete pad. The wires must be pulled, and then the trench and milled area must be concreted and asphalted.

2 LAYOUT AND ORIENTATION OF SENSORS

Airport pavements are designed to withstand the rolling weight of a fully loaded airplane. Over time, due to the impacts that are constantly applied on the pavement, and the heat during summer, pavement distresses appear on the surface, such as slippage, cracking, and surface shoving. The location and orientation of sensors in the pavement are established through studying the major Airbus and Boeing airplanes frequenting the airport. Each different airplane has unique wheel spacing and landing gear, which really determines the location of the sensors and the spacing between them. The nine different types of aircraft analyzed were the B737-300, B747-300, B757-300, B767-300, B767-300 ER, B777-300 Baseline, B777-300 ER, A330-300, A380-800.

The colored dots in Figure 1 indicate the different landing gear location of the distinctive airplanes mentioned above with the sensors positioned in transverse and longitudinal directions at appropriate spacing to enable data capture.

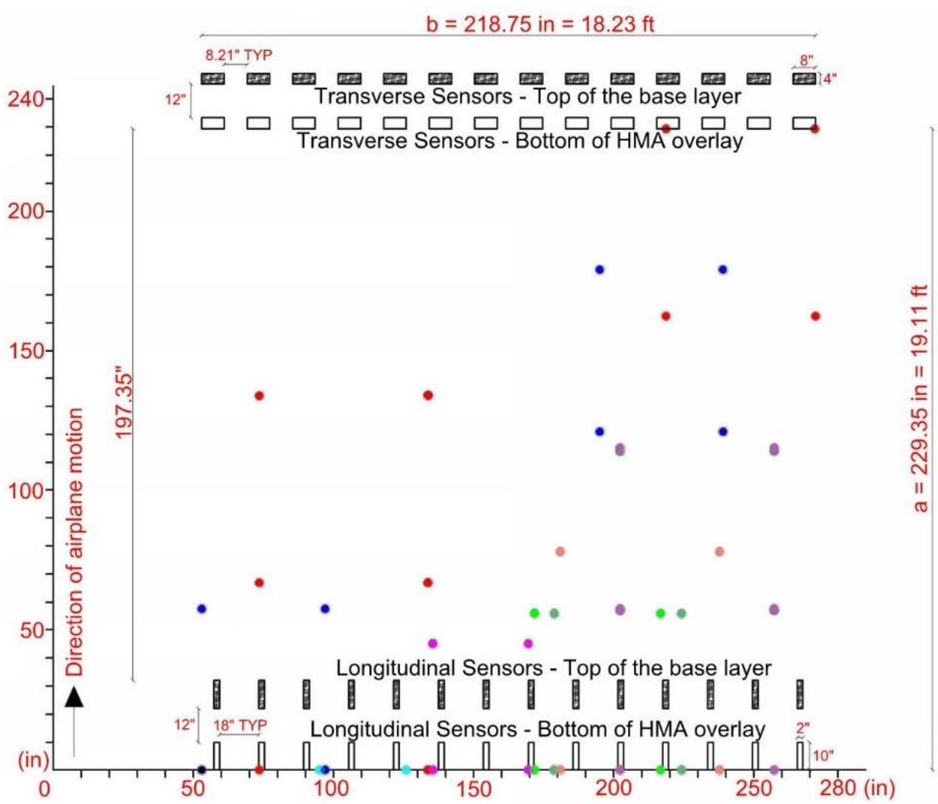

Figure 1. Position of the wheels of nine different aircraft (Singh and Melo 2017).

3 SCIENCE OF THE SYSTEM

The concept behind this new idea of installing strain gage sensors on airport pavements is to detect delamination of the runway surface. In a tightly bonded, homogenous pavement that does not show any form of delamination, compression is registered at the top surface, while tension is registered at the bottom (Figure 2). However, when the surface delaminates, the upper HMA layer acts independently of the lower layer. Thus, we have two independent neutral axes, as in Figure 2. This finding created the logic that if the change in strain pattern can be detected, delamination will also be detected (Singh and Cook 2016). Thus, half the sensors (28) are on the bottom of the top layer, and half are on top of the bottom layer (28).

4 DESIGN AND DRAWINGS OF THE SYSTEM

The surface must have sensors installed at two elevations, and wires must be taken off-pavement as far as the safety regulations require. And then, a platform is required for the DAQ.

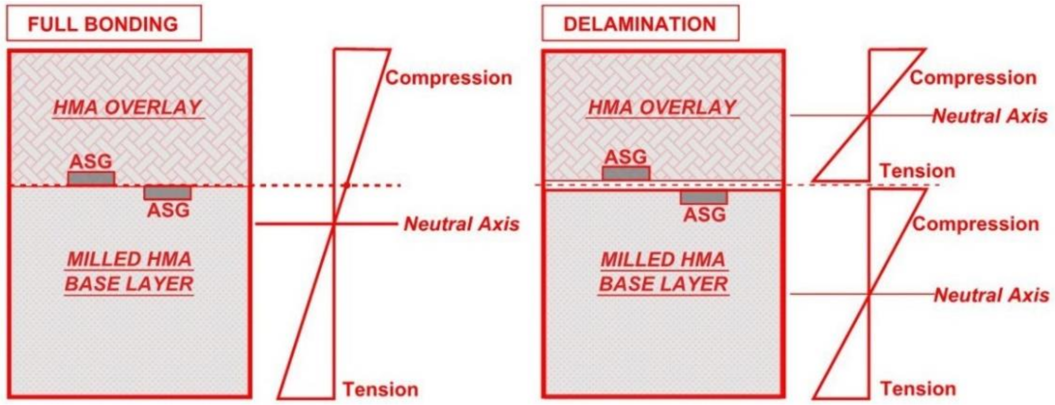

Figure 2. Neutral axis in bonding and delamination (Modified from Cook *et al.* 2016).

5 DESIGN AND DRAWINGS OF THE SYSTEM

There are many different types of elements put together to ensure that the system will achieve its design intent. First, we know that the surface must have sensors installed at two elevations; we know that wires must be taken off-pavement as far as the safety regulations require. And then, a platform is required for the data acquisition cabinet (Singh and Cook 2015).

6 MILLING OF EXISTING ASPHALT

The milling of existing asphalt to a depth of 3 inches is an essential part of the strain gage sensor installation (Figure 3). This is the area where the sensors will be installed to collect the data. Besides, the upper 3 inches is the top course of any pavement that is redone over time. This is what creates the weak interface that causes a disconnect between the upper layer and base layer.

Figure 3. The milled area for the sensor location.

7 TRENCHING AND EXCAVATION

There is a long trench excavated for the conduits from the taxiway to off-runway, while another excavation is made for the pull box. The length is determined by (i) minimum distance off-runway required for airport safety, and (ii) maximum distance before signals from sensors degrade (usually 500 ft.). The trench must be designed to accommodate lighting cans and at least four 2-inch conduits and be at a depth of 18 inches or more to remain safe under vehicular traffic.

8 SENSORS

It is important to ensure that the 56 sensors are buried in the asphalt at a depth of 3". The thickness of the sensor is ½-inch; hence, the recessed sensors must be buried deeper than 3". This thickness, together with the strength of the asphalt concrete, will avoid any instant damages to the sensor caused by the weight of the aircraft. Figure 4 shows the sensors in the pavement.

All the sensors were set in place with asphalt emulsion tack coating to secure the sensors in place. Electricians finalized all wiring connections and routed all 56 wires through the two lighting cans. Wires were then pulled the next day from the lighting cans to the pullbox and up to the DAQ platform. The electricians came back to connect the sensor wires to the DAQ system, connect the camera, and hook up the photovoltaic solar system to power the DAQ equipment.

Figure 4. Sensors are secured in place.

9 HIGH STRENGTH CONCRETE (5000-PSI) AND DAQ PLATFORM

The use of 5000-psi concrete in the trench was to ensure that its strength adequately withstands the weight of the aircraft and prevent this distressed spot from settling under aircraft rolling weight. For these reasons, only concrete is allowed in the trench for the base layer and below.

However, the DAQ platform (Figure 5), which is off-taxiway and 10' x 10' x 4", serves only as a rigid platform for the DAQ cabinet and solar panels, and can be sufficient at only 3000-psi. Nevertheless, it is problematic to order two batches of concrete from the concrete supplier for such small quantities. Hence, 5000-psi was used for the platform, as well.

Figure 5. DAQ platform concrete and equipment.

10 ASPHALT PAVING

The depth of the pavement is only 3" which calls for two lifts of asphalt. The first lift is placed, and laborers spread the first layer of asphalt evenly on the paving area. A walk-behindcompactor and a road roller are used to achieve a compaction of 100%. The same process is performed on the second and final layer of asphalt. But the final layer also uses sheep foot rollers. The asphalt paving is also performed on the taxiway trench, while the trenching area off-runway was topped off with dirt. Figure 6 has pictures on the asphalt paving.

Figure 6. Placing hot mix asphalt.

11 DAQ PLATFORM AND EQUIPMENT

Though this is a slab-on-grade for all practical purposes, the weight on the platform of the DAQ cabinet and solar power is not excessive. However, to avoid any damage in the event that vehicular traffic drives over the platform, it is necessary for the platform to be at least 4” thick and be reinforced, for which a wire roll is sufficient.

The equipment installed on the DAQ platform (data logger and multiplexor) are programmed to record and communicate data transmitted from the sensors. The equipment is charged by solar panels positioned above the equipment. To maximize the electricity generated, the solar panels are oriented south. A battery helps to store energy for night operations.

12 PROJECT SCHEDULING

The duration for the sensor installation project was five working days. Some activities are best performed at night such as, trenching, saw cutting, grinding, and chipping. Other activities are best when performed during day, such as concrete placement, forming, wiring, sensor installation. There is one primary reason why night work is best for this project: to avoid the severe jet blast.

In the beginning of the project, the taxiway was barricaded and closed off to aircraft. The contractors milled the asphalt overlay and excavated the trench and pullbox. They recessed the sensors and saw-cut the asphalt base layer for the sensor wires. While the saw cutting on the taxiway took place, the excavation in soil in the off-runway trench also commenced. A line was sprayed on the dirt by the surveyor indicating the path to be excavated. The asphalt on the runway trench was saw cut and busted. The sequence of these activities was setup to avoid any conflict or clash resulting in potential standby time. Figures 7 shows a sample schedule of work.

13 CONCLUSIONS

Strain gauge sensor installation on an operating airport can be challenging due to the limitation of time. Selecting the right contractor to perform the task is very important. They must be well equipped, have many experienced workers, and be familiar with ground, site, and electrical work.

It is important that before a contractor is selected, to meet with them, go through their past work history, and make sure they can meet the work schedule. The success of the strain gage sensor installation at the Honolulu airport depends a lot on good decision making.

SCHEDULE: Night 1 - Excavating & Trenching																										
Activity ID	Tasks	Dur. (min)	Time (hours)																							
			40.0		80.0		120.0		160.0		200.0		240.0		280.0		320.0		360.0		400		440.0		480.0	
N1-01	Close-off Runway	20	3																							
N1-02	Survey & Layout	40	3	3																						
N1-03	Spray Paint Saw Cut Line	20			1																					
N1-04	Sawcutting	80				2	2	2	2																	
N1-05	Milling	120					3	3	3	3	3	3														
N1-06	Trenching Off-Runway	180							3	3	3	3	3	3	3	3	3									
N1-07	Breaking Existing Ashphalt	60							2	2	2															
N1-08	Trenching On-Runway	180								2	2	2	3	3	3	3	3	3								
N1-09	Set Pullbox	40																2	2							
N1-10	Install Conduit Off-Runway	120										4	4	4	4	4	4									
N1-11	Install Conduit On-Runway	120																4	4	4	4	4	4			
N1-12	Form DAQ	40																2	2							
N1-13	Electrical Stub up on DAQ	40																		2	2					
N1-14	Set Lighting Cans	20																		2						
N1-15	Concrete Placement	120																		4	4	4	4	4	4	
N1-16	Clean-Up & Clear out Equipment	20																								4

SCHEDULE: Night 2 - Sensor and Wire Preparation																										
Activity ID	Tasks	Dur. (min)	Time (hours)																							
			40.0		80.0		120.0		160.0		200.0		240.0		280.0		320.0		360.0		400		440.0		480.0	
N2-01	Sensor Layout	40	3	3	3	3																				
N2-02	Recessed Sensor Prep	120					3	3	3	3	3	3														
N2-03	Saw Cutting for Sensor Wire	180											2	2	2	2	2	2	2	2	2					
N2-04	Clean-Up & Clear out Equipment	20																				4				

Figure 7. Work tasks and schedule duration.

Acknowledgments

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