Concrete Overload Test at the FAA National Airport Pavement Test Facility

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Abstract

To evaluate the ICAO Overload Criterion for rigid pavements, the Federal Aviation Administration (FAA) is conducting full-scale tests on a new concrete overlay pavement. At the National Airport Pavement Test Facility (NAPTF), the test pavement was constructed with a 9-in thick Portland cement concrete (PCC) surface layer and a 10-in thick aggregate subbase placed on medium strength subgrade. The FAA P-501 standard materials with a design flexural strength of 650 psi were used to build PCC slabs. Various types of instrumentation sensors were installed in the pavement to measure subgrade moisture, concrete temperature, slab movement, and dynamic strain responses. The FAA P-501 concrete materials were characterized by the flexural strength from laboratory cured beam samples and the in-situ modulus derived from portable seismic pavement analyzer (PSPA) testing on as-build slabs.

Introduction

The purpose of an airfield pavement is to provide a surface on which aircraft takeoffs, landings, and other operations may be safely conducted. Appropriate pavement rating allow for adequate pavement utilization at a reasonable cost, with the optimization of pavement economics that vary with local operational conditions. The ACN/PCN system of rating airport pavements is designated by the International Civil Aviation Organization (ICAO) as the only approved method for reporting strength. The FAA has adopted the method and it is referred to as the Aircraft Classification Number–Pavement Classification Number (ACN–PCN). ACN is a number that expresses the relative effect of an aircraft at a given configuration on a pavement structure for a specified standard subgrade strength. PCN is a number that expresses the load-carrying capacity of a pavement for unrestricted operations. The concept of ACN-PCN method is structured so a pavement with a particular PCN value can support an aircraft that has an ACN value equal to or less than the pavement's PCN value. The FAA Advisory Circular 150/5335-5C (FAA 2014) provides guidance on reporting airport pavement strength and is mandatory for all projects funded with federal grant money through the AIP program.

In the life of a pavement, it is possible that either the current or future traffic will load the pavement in such a manner that the assigned PCN rating is exceeded. Unless severely overloaded, it is most unlikely that a pavement will suddenly or catastrophically fail. Failure is most often recognized in terms of common pavement distresses such as rutting, cracking, and noticeably intolerable roughness that both pilots and passengers experience. Regular overload can substantially reduce the

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design life of a pavement, resulting in high rehabilitation costs and the inconvenience of a main runway or taxiway out of action. According to clause 20.1.1 of ICAO Annex 14 (ICAO 2013), occasional movements by aircraft on rigid pavements with ACN values not exceeding 5 percent above the reported PCN should not adversely affect the pavement.

Research Objective

Although the ICAO Overload Criterion represents a balance between operational flexibility and the need to avoid undue damage to pavements, it is still somewhat arbitrary. For instance, limited Construction Cycle 6 (CC6) test data demonstrated that one-time application of rupture load (equal or exceed slab strength) did not necessarily shorten pavement life (Brill 2013). Therefore, the objective of overload tests is to develop rational overload criteria for airfield rigid pavements.

Test Pavement Structure

As a part of comprehensive Construction Cycle 8 (Yin 2013) experiment, the overload test area is 60 foot long and 60 foot wide between Station 330 and 390. The pavement is composed of 9 in P-501 concrete placed on 10 in P-154 granular subbase that is supported on medium strength subgrade. Longitudinal joints are placed so that pattern across the 54-foot width is 12 – 12 – 6 – 12– 12. A 3-foot wide asphalt shoulder is built on the sides of the test pavement. Both north and south side have ten 12- by 12-ft slabs and the middle 6-foot slabs are used as transition slabs. A 12 feet joint spacing was selected because it would be long enough to be consistent with field applications, but short enough to minimize cracking due to warping, especially with the thin slabs. Past NAPTF studies have shown that the stiff base for a concrete surface layer causes curling liftoff to be substantially higher, and the resulting corner stresses also higher as the middle of the slab cannot deflect downward, all of the curl is forced to the edges. The transverse joints were consequently decided to be undowelled. All longitudinal joints are doweled and all dowels are 1 inch in diameter. The layout of test pavement is given in Figure 1.

Concrete Mix Designs

Based on past NAPTF experience with concrete mixes, the cementitious material content was limited at 470 pounds per cubic yard. The target water/cementitious ratio and air content were 0.45 and 6.0%, respectively (FAA 2014). This decision was specifically made to control flexural strength so that it would not become abnormally high. Mixes previously used at the NAPTF containing standard FAA material proportions were found to obtain flexural strengths well above 900 psi, giving rise to the concern that the concrete at the NAPTF would not represent standard mixes used at airports throughout the United States. Therefore the target strength for the mix was 650 psi flexural strength. In addition, Type F fly ash (30% by weight) was used as a partial replacement for cement to control the ASR which was observed in CC6.

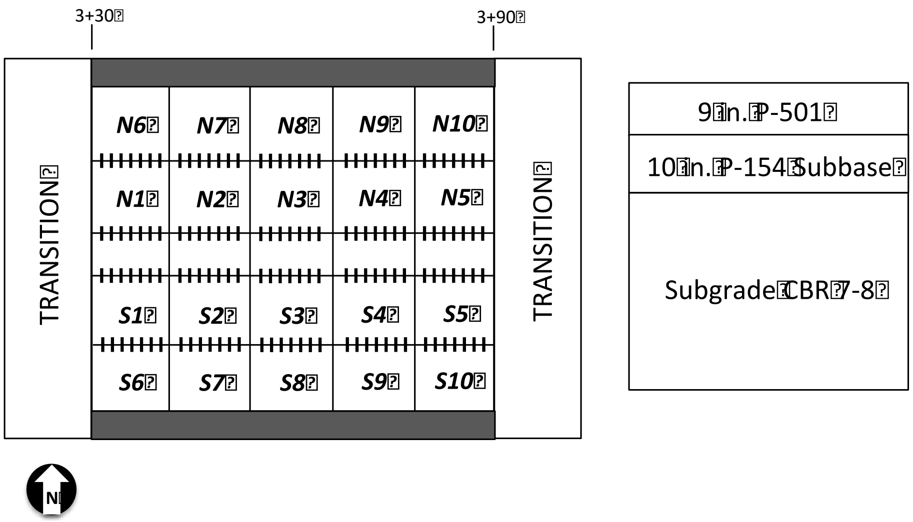

Figure 1. General layout of test pavement. Stationing is shown in hundreds of feet (100 ft. = 30.5 m).

Four local aggregates were considered in this study, and gradation charts of all four aggregate are shown in Figure 2. Tuckahoe 5/8", Penn Jersey 3/4", and Berks #8 contained a good amount of coarse (plus 3/8 in.) particles are the high quality, inert filler sizes. Tuckahoe Sand contained fine (minus No.8) particles give the mixture workability. An effective blending was obviously needed for the intermediate (minus 3/8 in. and plus No.8) particles are the intermediate particles that fill major voids, reduce the need for the fine material, and therefore aid in mix mobility. A total of four blended gradations were obtained using roughly 60% coarse aggregate and 40% fine aggregate by total volume. Given the similar gradation characteristics of Penn Jersey 3/4" and Berks #8, Berks #8 was only used in one blending. Blended gradations are given Figure 3.

Blended aggregates were first evaluated using coarseness-workability chart. As shown in Figure 4, all blended aggregates are within Zone II is generally considered to be reasonable mixes. While Zone I is supposed to be gap graded with very little amounts of intermediate, Zone III has a large majority of intermediate and very little coarse aggregate. The Zone IV and Zone V correlate with the extreme sandiness and rockiness.

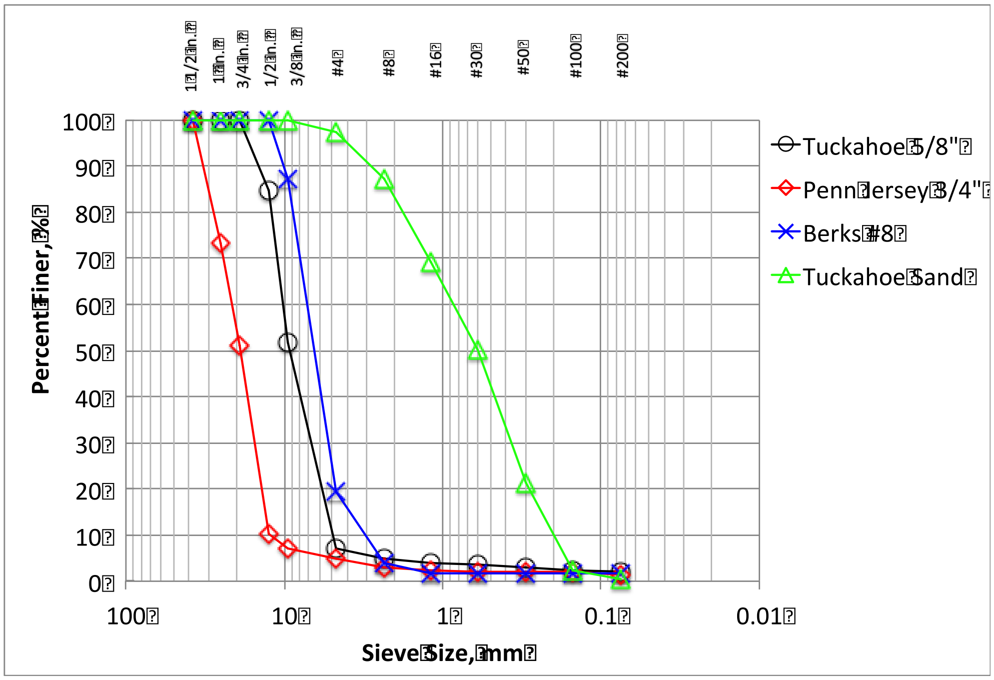

Figure 2. Gradation chart of individual aggregate.

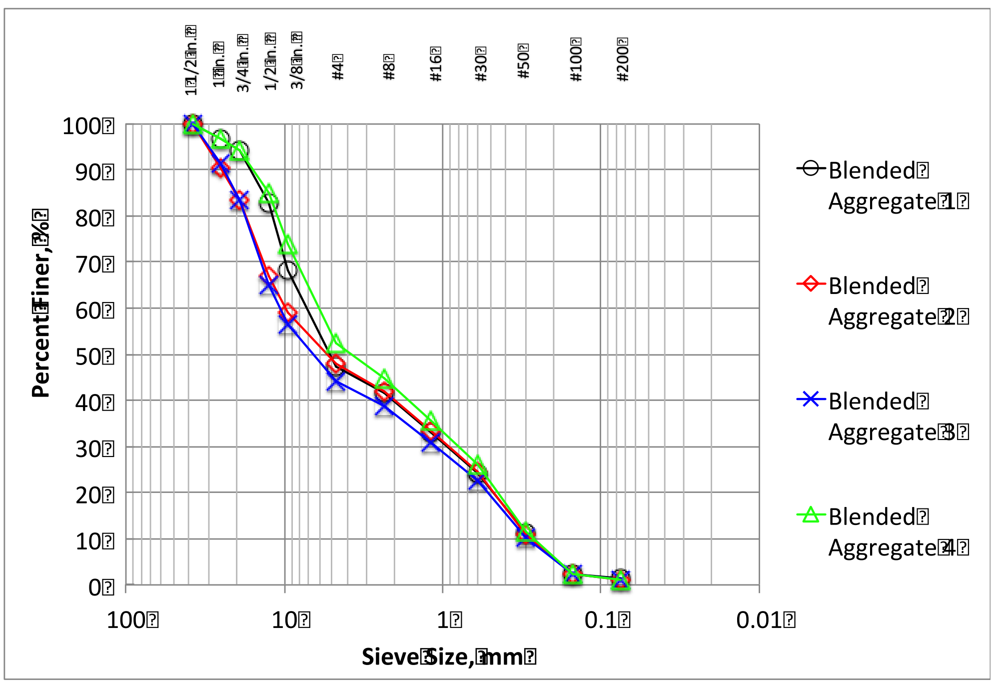

Figure 3. Gradation chart of blended aggregates.

The second tool used to evaluate blended aggregates was Percent Retained (PR) chart. The PR chart is commonly called the "8-18 chart" due to a minimum of 8% and a maximum of 18% required as gradation limits for sieves between 1 in. and

No.30. These limited are marked as dashed lines on Figure 5. In addition, the total gradation (on a volumetric basis) is divided into three areas, coarse, intermediate, and fine. As shown in Figure 5, there was a double hump, with slightly more materials retained on the 1/2 in., No.4, and No.50 sieves. There was a marginal lack of intermediate size material on the #8 sieve. Although there were two sieves that fell outside the "8-18" band, that did not necessarily indicate the mixtures would be unacceptable. Because the focus of 650 psi mix design was to develop a low strength mix that would be placed in the field without shrinkage and finishing concerns, all four blended aggregates were decided to be the starting point for trial mixes that confirm the mix properties. Accordingly, four mix designs were developed, as listed in Table 1.

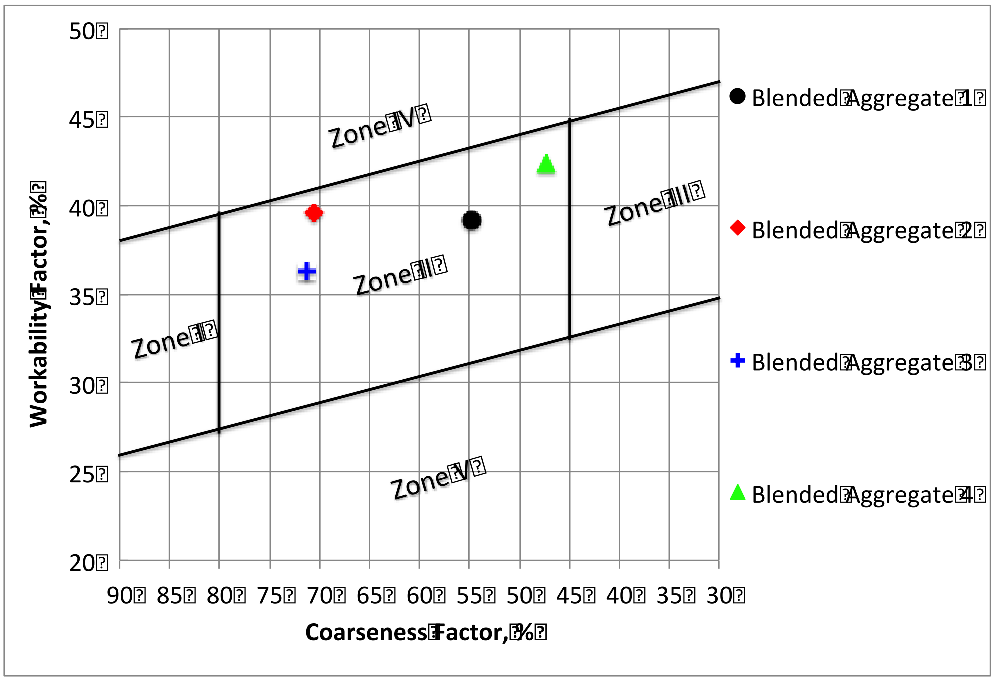

Figure 4. Coarseness-Workability chart.

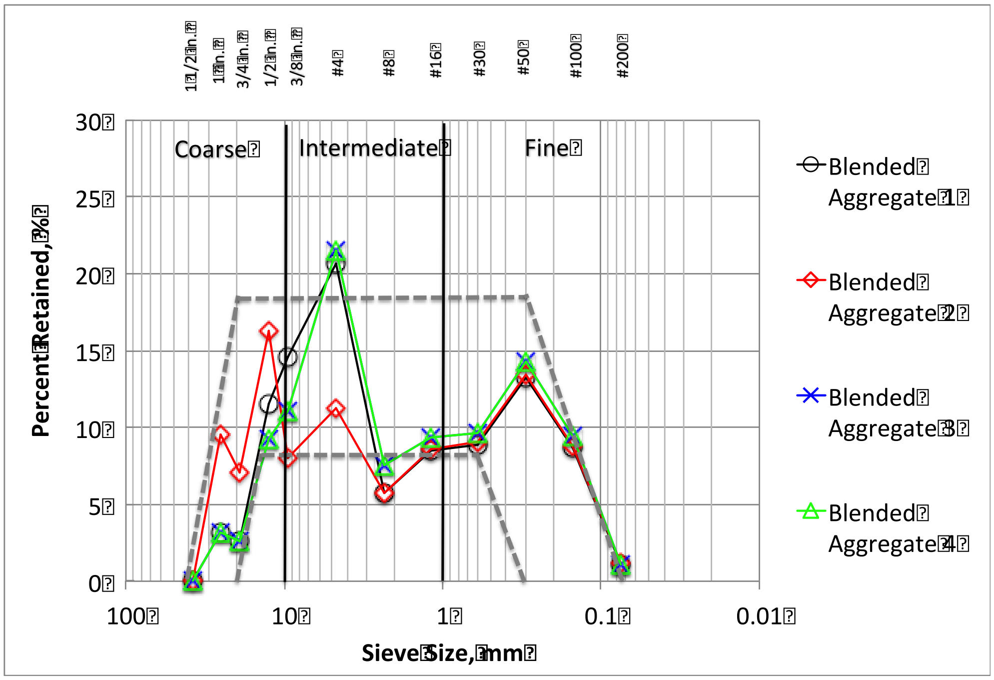

Figure 5. Percent Retained chart.

Table 1. Trial mix designs.

Materials	Proportions, lbs/cy			
	Mix Design 1	Mix Design 2	Mix Design 3	Mix Design 4
Tuckahoe 5/8"	1315	650	660	860
Penn Jersey 3/4"	365	983	1090	368
Berks #8	0	0	0	336
Tuckahoe Sand	1355	1410	1285	1520
Water	212			
Type 1 Portland Cement	329			
Type F Fly Ash	141			
Air Content, %	6			
W/C Ratio	0.45			

In order to track strength gain in the mix, the flexural and compressive strength of all four batched mixes were measured in accordance to ASTM C78 (ASTM 2007) and C39 (ASTM 2005), respectively. As shown in Figure 6, the flexural strength of all mixes started between 400-450 psi at 7 days. After 28 days, Mix 1 had the highest average break strength, 560 psi, which was 10% less than the target strength, 650 psi. Given the moderate dosage level of fly ash, the mix was expected to continue to gain strength over time. For the compressive strength (see Figure 7), Mix 1 showed the most uniform strength development over the testing period among the mixes. In addition, Mix 1 was more workable during the batching process, it was therefore selected for the final concrete placement to facilitate instrumentations.

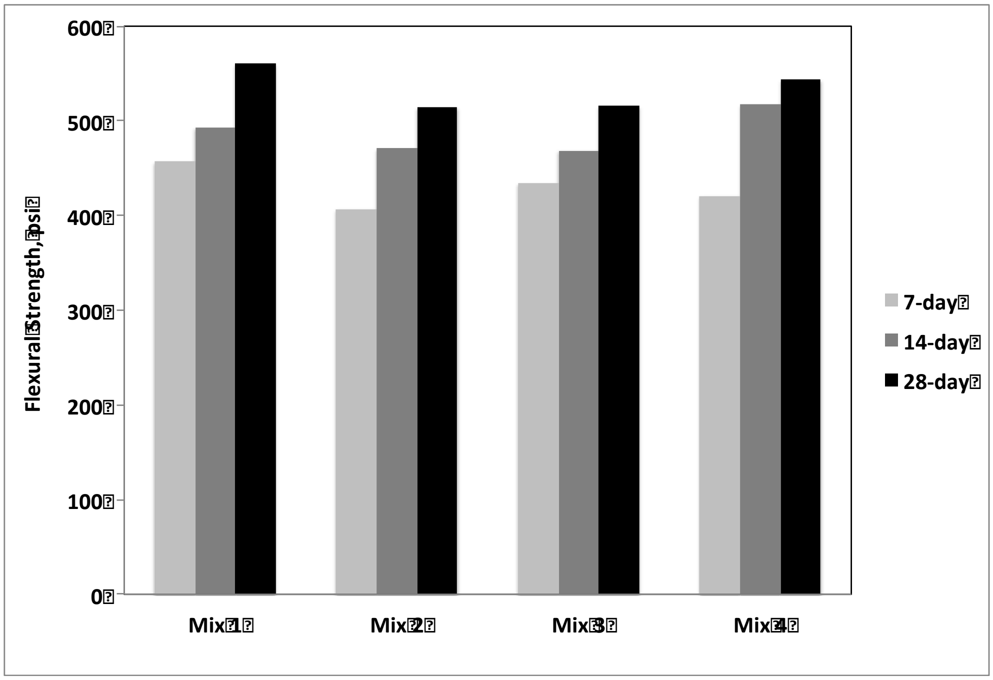

Figure 6. Flexural strength of trial mixes.

Construction and Instrumentation

The construction of new test pavement began with the demolition of remained Construction Cycle 6 (CC6) over the medium strength subgrade. The demolition consisted of the removal of the surface concrete layer (P-501), econocrete (P-306) and hot mix asphalt (HMA) (P-403) subbase, aggregate base (P-154), and the clay subgrade.

Subgrade Preparation

The subgrade target CBR value range was 7-8 with a tolerance of -0.5 to 0.5. Based upon testing results, the calculated and estimated ranges for the CBR were within the established criteria. Consequently, it was determined, based on prior experience, that it would only be necessary to rework the top of subgrade. The procedure used to achieve the required results included trimming to final grade, tilling to a minimum depth of 8 inches, monitoring moisture content, and making adjustments until the target CBR value was achieved. The final CBR subgrade values are 7.2 and 7.4 for the north and south side, respectively. While the plate load test results for the subgrade exhibited some variation, the average k value was 110 pci. on the north side, and 131 pci. on the south side.

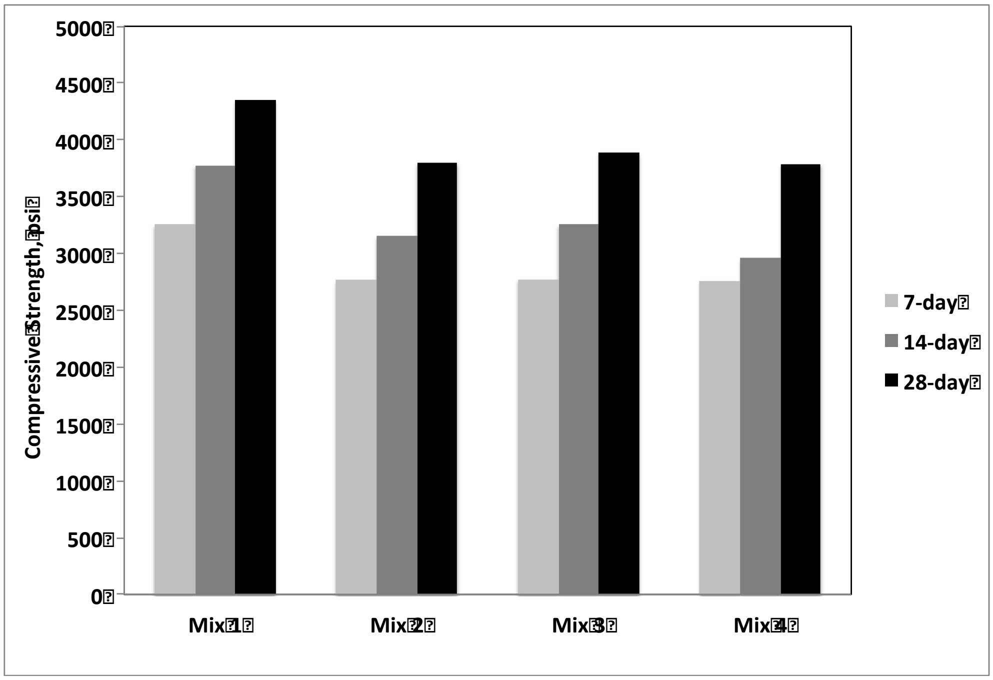

Figure 7. Compressive strength of trial mixes.

Subbase Construction

A P-154 granular subbase course was placed on the prepared subgrade. Moisture, gradation, and density testing were conducted on the basis of 50 square yard sublots, to control the granular material and placement. The gradation samples showed the materials were within the P-154 specification limits. The average density was 97%, and the average moisture content was 7.6%. The plate load tests were performed on the top of subbase and the average k value was 216 pci. on the north side, and 272 pci. on the south side.

Concrete Paving

The total width of paving was 54 feet. The effort started with setting the forms. There were two placements, spaced 7 days apart. The first placement was poured on Aug 13, 2015 and covered two inner lanes, which included ten test slabs. The second placement was poured on Aug 20, 2015 and covered the center and two outer lanes. The steel dowels used measured 1 inch in diameter and 19 inches in length. They were placed at the mid-thickness of the concrete. They were spaced at 12 in in the longitudinal joints. The surface of the concrete was given a float finish after the screed had passed the given location. Water soaked burlap strips were placed over the surfaces of the slabs at the end of the day. The burlap was in turn covered with plastic sheets in order to retain the moisture for curing the concrete over a 28-day period. Approximately 24 hours of each placement, the saw cut of transverse joints took place. The process consisted of removing the burlap and plastic sheets, surveying the joint locations, marking the joints with string and paint, and then sawing the joints. All transverse joints were sawn at D/3.

Instrumentation
Prior to the placement of surface concrete layer, all subgrade, subbase and concrete slab instrumentation had to be installed. The selection of gages was based on reliability, accuracy, price, and ease of handling at the construction site. Instrumentation details are given in Figure 8.

Vertical movement of eight slabs was monitored by LVDTs at the corner. To install LVDTs, a steel bar was first driven into the subbase to serve as a stationary reference point. Each LVDT was then attached to the steel bar, and a rebar chair was used to secure the height of the LVDT at its mid- position as the slab was constructed to make sure that both up and down movement from the as- built position could be recorded.

A pair of embedded strain gages was installed in eight slabs to measure strain responses near the top and bottom of the slab. These gages were located along the loaded longitudinal or transverse joint. Embedded strain gages were installed during the paving operation. Rebar chairs were used to make certain the gages were set at the proper height, 1 in above the bottom and 1 in below the surface.

Thermocouple trees were installed in two slabs to monitor slab temperature gradients. Each tree consists of three thermocouples to measure temperature at the bottom, middle and top of the slab.

In addition, moisture sensors were installed at two locations to monitor the moisture content. These sensors were located at 6 in below the subgrade surface during the subgrade preparation.

Concrete Material Characterization
The initiation of longitudinal top-down cracking has been previously observed, for example CC6, and various explanations for the causes of this crack initiation have been postulated. This top-down cracking is cracks resulting from slab corner curling. To enrich the database from the full-scale testing in this regard, it was recommended that concrete samples be made for supplemental materials characterization. By measuring flexure strengths and establishing a relationship with the elastic modulus of concrete, a better understanding of this top-down cracking mechanism can be achieved.

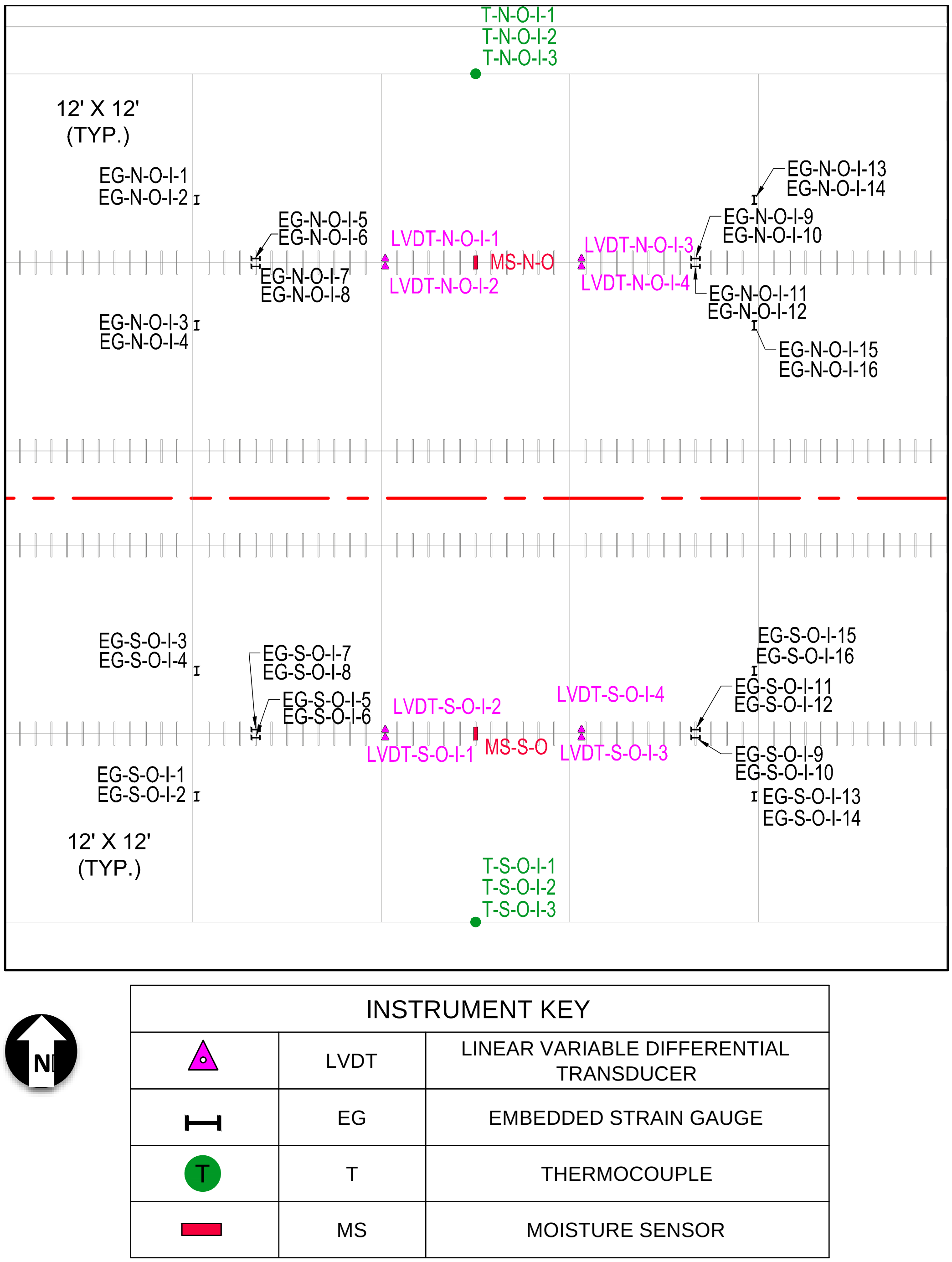

Figure 8. Instrumentation layout.

During concrete paving, beam samples were collected from the fresh concrete in the truck. The average onsite W/C ratio was 0.35 and 0.40 for Placement 1 and 2, respectively. The flexural strength of laboratory cured beam samples at 7- and 28-day is given in Figure 9. On average, the strength gain was 22% from 7 to 28 days. Due to lower W/C ratios, samples from both placements showed about 10%

higher strength than the samples of trial mix. The two-sample t-test was used to determine if the mean flexural strength from two placements are equal. Unpaired samples and equal variance were assumed. A two-tailed *p-value* of 0.5594 suggested that the difference in the flexural strength of placement 1 and 2 was not statistically significant. Figure 9 indicates a fairly uniform concrete materials and excellent construction.

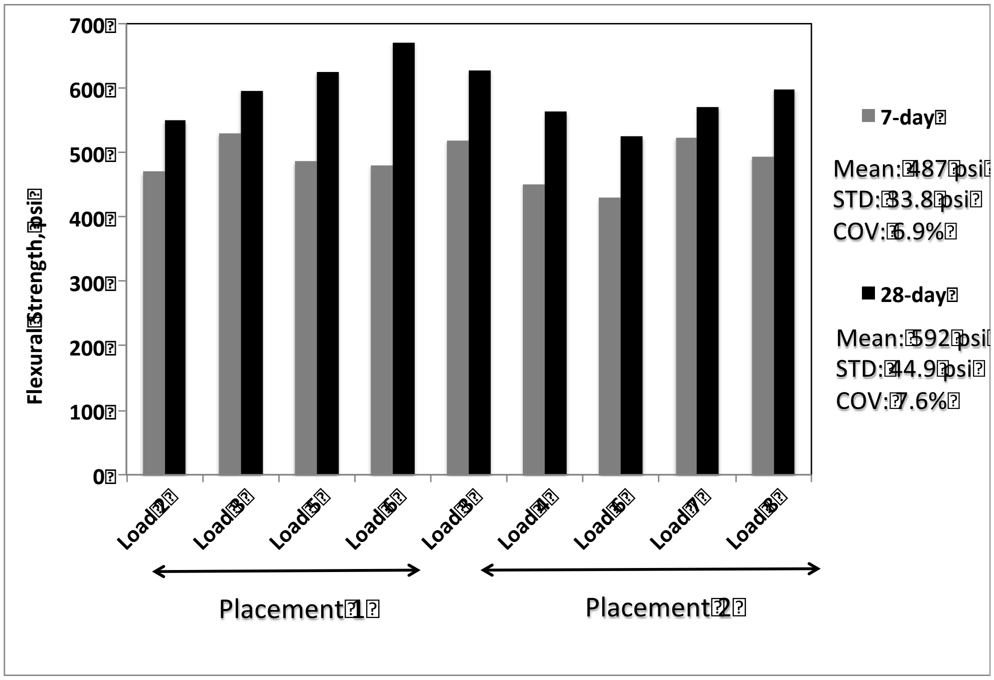

Figure 9. 7- and 28-day flexural strength from construction.

The use of the portable seismic pavement analyzer (PSPA) provides a means of rapidly and non-destructively measuring pavement properties via ultrasonic surface waves. In this study, PSPA was used to measure the in-situ modulus of P-501 layer. At each slab center, multiple PSPA measurements were collected at different orientations, and the average values were reported. As shown in Figure 10, the 28-day in-situ modulus was quite consistent from one slab to another with a mean value of 4310 ksi. The average COV was 4.7 percent. This variability level agrees well with the value reported by Alexander (1996). The PSPA data verified the excellence of construction quality.

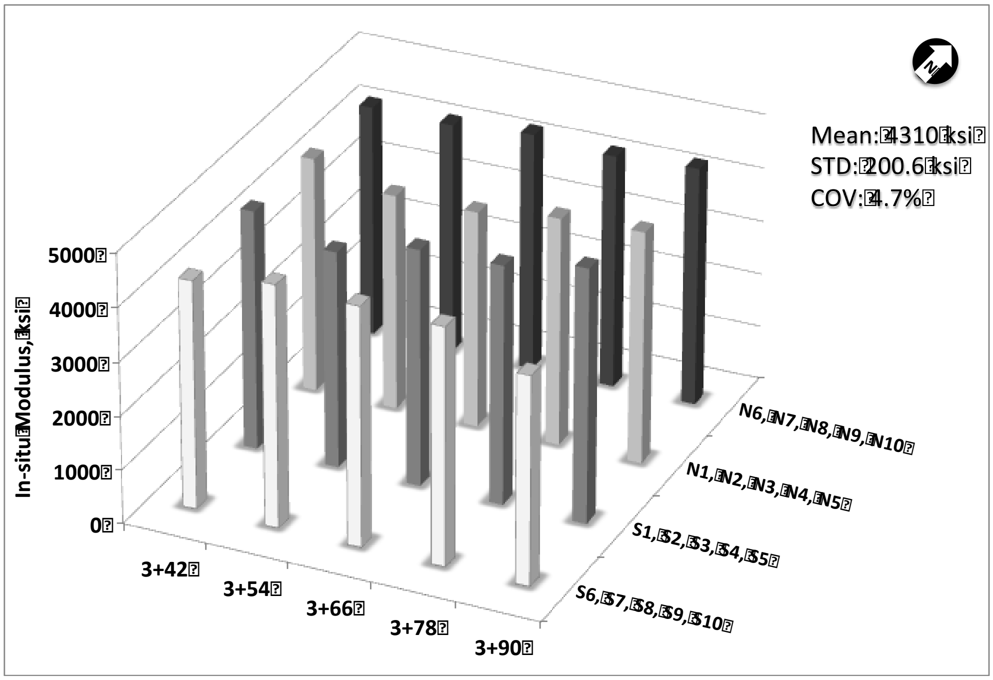

Figure 10. 28-day in-situ modulus.

Concluding Remarks

This paper presents an on-going overload experiment at the FAA's NAPTF. To evaluate the ICAO Overload Criterion on rigid pavements, a test pavement was constructed and instrumented. The test pavement consisted of 9-in thick PCC surface layer, 10-in thick aggregate subbase, and medium strength subgrade. The traffic test is projected to begin in the fall of 2015. This overload test is expected to generate full-scale test data, which will be of immediate interest to airport operations.

Acknowledgement

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