TEMPERATURE MODELS

INTRODUCTION

Background

Results from the effort described the interrelationships that concrete temperature, strength and modulus of elasticity have with the cement degree of hydration.[1,2] Basically, the cement rate of hydration dictates the rate of temperature development in the concrete as well as the development of strength and other mechanical properties. Set time is also affected by the development of degree of hydration. According to Byfors[3] and the model currently used in HIPERPAV.

Objective

The objective of this study is to present the calibration and validation results of this model for all the five field verification sites described in detail in references 4 and 5.

Parameters

The temperature model in HIPERPAV is based on the general differential equation for heat transfer.[2] The temperature of the concrete during the hydration process is predicted as a function of the generated heat of hydration in the concrete as well as a function of the boundary conditions. These boundary conditions are convection, irradiation, and solar absorption at the top surface of the pavement and conduction at the bottom surface of the pavement.

The parameters that are used for the verification of this model include:

1. Pavement Design including: Pavement thickness
2. Mix Design including: Total heat of hydration, hydration parameters to predict the heat development in the concrete, coarse aggregate type to determine overall mix properties like specific heat, density, etc.
3. Climatic Data including: Temperature of the air, solar radiation, relative humidity, and wind speed
4. Construction Data including: Curing method, time of day of construction, time at application of curing, initial mix temperature, and initial subbase temperature

During the field verification of HIPERPAV, all the above parameters were measured in the field or obtained through laboratory tests.

Calibration

The core of the temperature model is formed by a transient finite element algorithm that evaluates the heat transfer process between the interactions of the environment, pavement boundary conditions and heat generated in the concrete during hydration. The procedure to verify this model started by performing a parametric study to determine the effects of each one of the parameters considered. The sensitivity of each of these parameters was assessed for the prediction of the concrete temperature as compared to the measured temperature in the field.

Statistical Fit

Comparisons of the predicted concrete temperature with the measured temperature in the field were made after the evaluation of each of the variables to determine the values that provided a better fit. The comparisons of predicted vs. measured temperature were made at 1 in from top, middle and 1 in from bottom of the slabs. Also, to evaluate the thermal gradient through the slab, the temperature differences between the top and bottom locations were compared as well. A statistical fit was obtained by means of least square regression A summary of the regression constants for the comparison between measured and predicted PCC temperatures is presented in table below.

Table 1. Statistical summary for coefficient of determination to the 45º line.

Slabs Selected for Calibration

	MN S2	MN S3	NE S1	AZ S4	AZ S5	TX S1	TX S4	NC S1	NC S4
1" from Top	0.68	0.86	0.89	0.80	0.82	0.90	0.84	0.86	0.80
Middle	0.79	0.91	0.93	0.87	0.83	0.89	0.59	0.76	0.79
1" from Bottom	0.92	0.95	0.93	0.84	0.93	0.94	0.88	0.97	0.86
Temperature differential from top to bottom reading	0.72	0.82	0.88	0.67	0.84	0.88	0.87	0.85	0.78
Average R^2	**0.78**	**0.89**	**0.91**	**0.80**	**0.86**	**0.90**	**0.80**	**0.86**	**0.81**

Slabs Selected for Validation

	MN S1	MN S4	NE S2	AZ S1	AZ S3	AZ S6	TX S2	TX S3	NC S2	NC S3
1" from Top	0.75	0.73	0.87	0.80	0.75	0.79	0.93	0.80	0.85	0.82
Middle	0.69	0.81	0.91	0.87	0.77	0.77	0.80	0.69	0.65	0.78
1" from Bottom	0.80	0.89	0.90	0.91	0.77	0.87	0.98	0.87	0.87	0.85
Temperature differential from top to bottom reading	0.90	0.81	0.76	0.80	0.74	0.84	0.88	0.83	0.84	0.83
Average R^2	**0.78**	**0.81**	**0.86**	**0.84**	**0.76**	**0.81**	**0.90**	**0.80**	**0.80**	**0.82**

The figures below present the measured vs. predicted temperature, for the slab No. 1 in State of Minnesota. The temperature comparison for other slabs in other slabs is shown in appendix B of reference 5.

MINNESOTA - VALIDATION

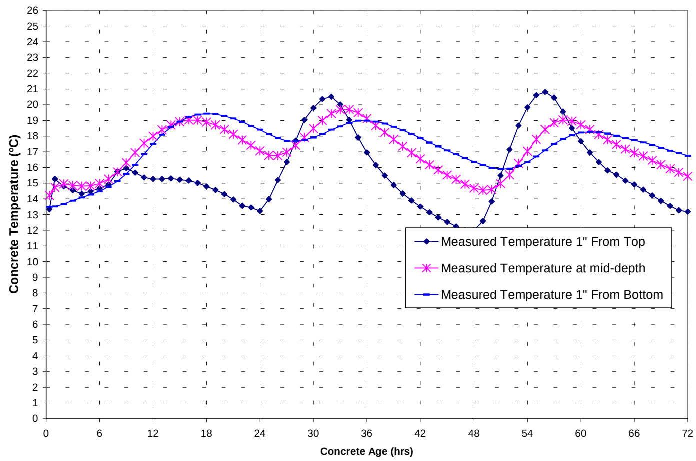

Figure 1. Measured concrete temperature top, middle, and bottom for Minnesota slab #1.

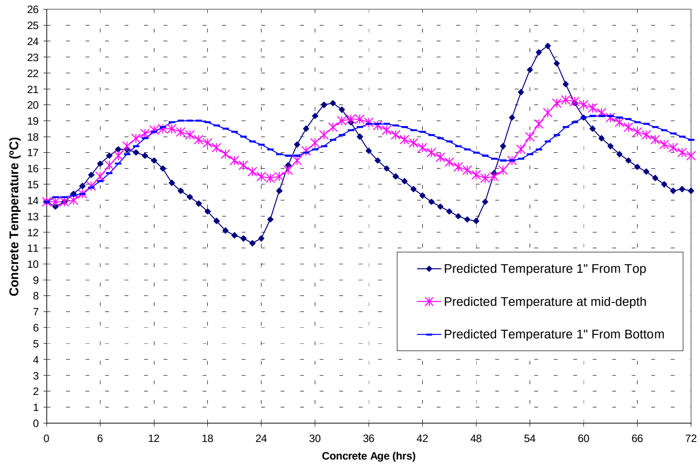

Figure 2. Predicted concrete temperature top, middle, and bottom for Minnesota slab #1.

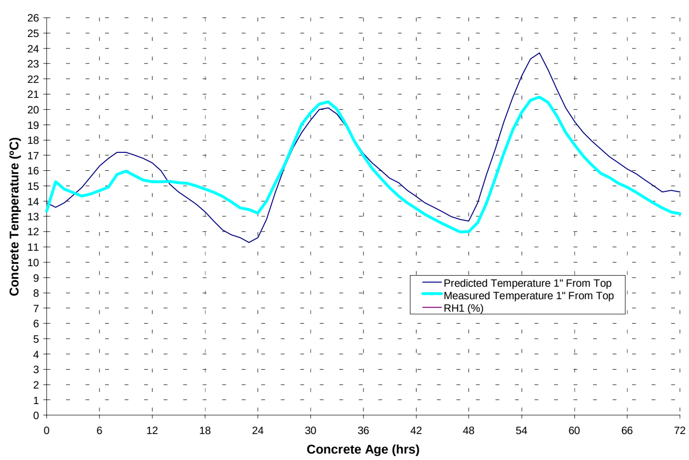

Figure 3. Concrete temperature 1 in from Top, Minnesota slab #1.

REFERENCES

(1) Technical Memorandum No. 1, *Description of HIPERPAV Calibration and Verification Study,*

(2) Technical Memorandum No. 6, *Priority Assessment for Calibration/Validation of the HIPERPAV Models*

(3) Jan Byfors, Plain Concrete at early ages, CBI, 1980.

(4) Technical Memorandum No. 15, Temperature Models

(5) Technical Memorandum No. 28, Results of the Calibration and Validation of the Temperature Model

(6) B. Frank McCullough and Robert Otto Rasmussen, "Fast Track Paving: Concrete Temperature Control and Traffic Opening Criteria for Bonded Concrete Overlays, Task G, Final Report,, FHWA, 1998.