

Coupled Thermal and Moisture Modeling of Jointed Plain Concrete Pavements: A Sensitivity Study

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Abstract

This study outlines a coupled thermal and moisture transfer simulation model to simulate the environmental effects that impact a concrete pavement slab through its internal relative humidity (RH) profile. The model is validated by use of observed temperature and internal RH field data from an in-situ concrete pavement test section. A sensitivity simulation of this coupled model for arid region concrete slabs is conducted to better assess the impact of localized climatic factors such as wind speed, air RH, and local rainfall distribution on the concrete slab's internal RH profile. Better understanding of the coupled effects of temperature and moisture will help improve predictions of critical concrete pavement factors such as moisture warping, differential drying shrinkage, chloride ion ingress, and other moisture durability-related concerns.

Introduction

The internal relative humidity (RH) of an in-service concrete slab correlates to both concrete durability and concrete performance including issues such as drying shrinkage, chloride ion ingress, sulfate attack, and others (Shoukry et al. 2011; West and Holmes 2005). Numerical models can be a useful tool in predicting the concrete's internal moisture distribution and understanding the factors affecting this distribution. Some of the major factors affecting internal moisture are the drying and wetting events on the slab surface. Drying cycles control the moisture loss of the slab whereas wetting processes govern the moisture gain, primarily through surface mechanisms. A model able to credibly characterize these loss- and gain-processes could provide reasonable predictions of the moisture distribution, thereby offering a better picture of moisture-related issues, including warping potential of concrete pavement slabs.

Numerical simulations have been popular to study the moisture transport within concrete (Bazant 2001; Xi et al. 1994; Bažant and Najjar 1972), but only a few models have adopted variable boundary conditions. Bažant proposed a highly nonlinear formula to characterize the moisture transport within a concrete structure at both saturated and unsaturated states (Bazant and Najjar 1971; Bažant and Najjar 1972; Bazant et al. 1982). In these studies, a constant ambient air RH was normally adopted with the concrete structure shielded from cyclic wetting and drying events. While useful for proof-of-concept research, this controlled boundary condition does not reflect the realities of in-service concrete slabs. Moisture distributions within such slabs depend on several uncontrollable factors including rainfall, ambient RH, local wind speed, etc. The inability to accommodate these factors in a model aiming to predict slab RH impedes the understanding of slab-stress distribution due to moisture and, ultimately, concrete pavement performance.

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This study simulates in-service slab-moisture distributions by use of a coupled heat-transfer and moisture-transport model that considers the moisture diffusivity variation with temperature fluctuation. The model considers the occurrences of the wetting and drying cycles probabilistically and accommodates the local wind speed, ambient air RH, rainfall, etc. The proposed model is validated by field data measuring both temperatures and RH within an in-service slab. Sensitivity studies are conducted to better understand the influences of rainfall, wind speed, and ambient RH on the moisture distributions within in-service concrete slabs.

Heat Transfer Model Development

Pavement temperatures are mainly controlled by the heat flux at the surface as the width and length of a pavement slab are far greater than the thickness. A one-dimensional heat transfer model is thus adequate to predict the temperature distribution of a slab and of its underlying layers to account for solar absorption, irradiation, convection, and conduction between layers as shown in Figure 1 (Gui et al. 2007; MEPDG 2004; Qin and Hiller 2011).

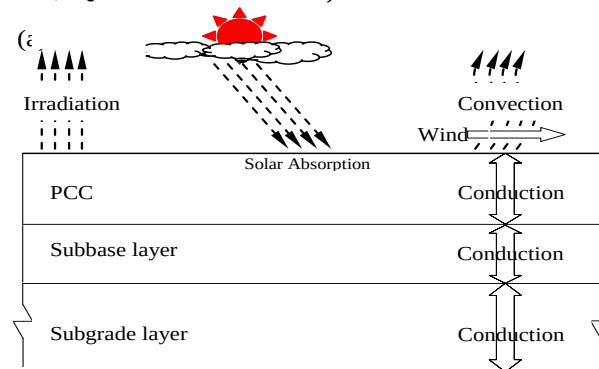


Figure 1. Schematic showing factors affecting the heat transfer model.

The temperature T of the media (the pavement slab and the underlying layers) can be described by the Fourier Equation:

$$\rho c \frac{\partial T}{\partial t} = \text{div}(k \cdot \text{grad}(T)) + q_{\text{hydra}} \quad (1)$$

Where k (W/(m·°C)) is the thermal conductivity of mediums; ρ (kg/m³) and c (J/(kg·°C)) are the density and heat capacity of mediums, respectively; q_{hydra} (W/m²) is the internal heat generation rate, for hardened concrete, $q_{\text{hydra}} = 0$.

The thermal capacity, density, and thermal conductivity of concrete have been well documented by previous researchers (Chung and Shin 2008; Kim et al. 2003; Khan 2002). These properties depend on concrete mixture characteristics, e.g., water-to-cement ratio, aggregate type, aggregate volume, and porosity of the concrete. Detailed values are site-specific and reasonably controllable parameters. Details of the thermal prediction model using both deterministic and probabilistic factors to account for solar absorption, irradiation, convection, and conduction between layers employed in this study can be found in (Qin 2011; Qin and Hiller 2011).

Moisture Mass Transport Model Development

Just as with the temperature prediction model, a one-dimensional finite element model suffices to simulate the moisture transport within the concrete slab due to a slab's unique geometry for most cases. The moisture content within concrete can be represented by the internal RH at a given depth within the concrete. According to the

law of mass conservation, the moisture transport equation can be expressed as (Kim and Lee 1999):

$$\frac{\partial RH}{\partial t} = \text{div}(D \cdot \text{grad}RH) + \frac{\partial RH_s}{\partial t} \quad (2)$$

Where $RH = RH(t, z)$ is a function of both time and depth; moisture diffusivity D (m^2/s) is a function of both humidity and porosity of concrete (Kim and Lee 1999; Li et al. 2008); and t is time, s ; $\partial RH_s / \partial t$ is the RH's dissipation rate, which depends on the hydration rate for early age concrete. For mature concrete, $\frac{\partial RH_s}{\partial t}$ approaches zero.

At saturation conditions, capillary suction dominates the moisture transfer within concrete, whereas at unsaturated conditions, vapor- and gas-pressure gradients govern movement (Hall 1989). A concrete slab's moisture diffusion thus depends on the pore moisture. This non-linear moisture transport can be characterized by an effective diffusivity as proposed by Bažant and Najjar (1972):

$$D = D_0 \left(\alpha_0 + \frac{1 - \alpha_0}{1 + \left(\frac{1 - RH}{1 - RH_c} \right)^n} \right) \quad (3)$$

Where D_0 is the moisture diffusivity at saturation; n is a regression coefficient describing nonlinearity of the diffusivity with respect to RH , ranging from 6 to 16 for concrete (Leech et al. 2003); $\alpha_0 = D_1/D_0$, where D_1 is the diffusivity of concrete with 0% RH; RH_c , typically ranging from 0.75 to 0.80, is a bifurcate below which the moisture migration occurs due to gas pressure but above which the migration is driven by capillary suction.

Eq.(2) needs to be normalized in order to reasonably simulate the moisture transport within a concrete slab. The moisture diffusivity is orders of magnitude lower than the dimension of the slab in terms of modeling, making the condition number of FEM stiffness matrix too large to ensure the transient moisture prediction to be correct and efficient. To circumvent this problem, a dimensionless scale is applied to rearrange Eq.(2). The rearrangement begins by introducing the following dimensionless variables:

$$\bar{t} = \frac{t}{t_0}, \bar{z} = \frac{z}{l_0} \quad (4)$$

Where $\bar{z}$ is a dimensional scale denoting the depth within the slab $0 \leq \bar{z} \leq 1$; l_0 is the thickness of the slab; t_0 (s) is the characteristic time of the diffusivity, $t_0 = l_0^2/D_0$, $\bar{t}$ is therefore a dimensionless scale referring to the time. Substituting Eq. (4) into (2) yields:

$$\frac{\partial RH}{\partial \bar{t}} = \frac{\partial}{\partial \bar{z}} \left(\frac{1}{Pe_m} \frac{\partial RH}{\partial \bar{z}} \right) \quad (5)$$

Where Pe_m is the Péclet number regarding mass transport, defined as:

$$Pe_m = \frac{Dt_0}{l_0^2} \quad (6)$$

With this scaling, Eq. (5) becomes easier to adapt both element length and time step to ensure the convergence of the mass transport Eq. (2) (Bažant and Kim 1991). It therefore overcomes the singularity of the stiffness matrix when the mass transport model is simulated under the finite element framework.

Boundary conditions. A numerical solution to Eq. (2) must specify a proper boundary condition to both the bottom and the top of a pavement slab. Moisture at the bottom is relatively stable and less affected by the moisture exchange between the slab and the underlying layers (Li et al. 2008). In this regard, the bottom of a pavement slab can be considered as a Neumann boundary with null moisture flux ($gradRH = 0$).

The occurrence of wetting and drying cycles complicates the mass transport at the pavement surface. During the drying cycles, moisture exchange at the top of the slab is a convection boundary, depending on factors such as the ambient air RH, wind speed, RH value at the top of the slab, etc. During the wetting cycles, RH at the top can be set to $RH=100\%$ (Bažant and Najjar 1972). The assumption is practical because, although the absorption may dominate the moisture intake in the top and the case of $RH>100\%$ may occur therein, the wetting front penetration usually occurs to a depth of $<1\text{cm}$ during a normal rain event (Bažant and Najjar 1972). An estimate for the upper boundary thus requires: (1) determination of when the wetting or drying events occur around a year cycle; and (2) characterization of the moisture evaporation rate during the drying cycles. Details of how this model accounts for these factors both deterministically and probabilistically can be found in (Qin 2011).

Temperature and moisture coupling theory

The diffusivity D varies with temperature as described previously. Theoretically, this correlation obeys rate process theory and can be characterized by the following equation (Bažant and Najjar 1972):

$$\frac{D_T}{D_0} = \frac{T}{T_0} \exp\left(\frac{Q}{RT_0} - \frac{Q}{RT}\right) = \Phi(T) \quad (7)$$

Where T is absolute temperature; T_0 is reference temperature (K), normally selected as room temperature; D_T and D_0 are the saturated diffusivity at temperatures T and T_0 , respectively; Q is the activation energy (enthalpy) of diffusion process; and R is the gas constant. The value of the activation energy was found to be roughly 1300cal/mole for mature concrete.

The internal concrete's pore RH also varies with temperature. Since the moisture-diffusion process is orders of magnitude less than the thermal-diffusivity process, the water content within a pore could be seen as a constant during a short period such as an hour or even a day. However, the temperature during this hour may change significantly, particularly near the surface. Thus, the pore RH must vary with the temperature. The correlation can be characterized by the hydrothermic coefficient κ ($^{\circ}\text{C}^{-1}$) using the following equation:

$$\frac{dRH_{eq}}{dt} = \frac{dRH}{dt} - \kappa \frac{dT}{dt} \quad (8)$$

Where the RH is the local pore RH; RH_{eq} is the equivalent pore humidity at temperature of T_0 . It merits noting that by varying T and RH , the saturated diffusion D_T should be estimated by use of RH_{eq} (Bažant and Najjar 1972). That is, the local saturated diffusivity has to be estimated by Eq. (9) using the effective diffusivity, D , from Eq. (3).

$$D_T = D(RH_{eq})_{T_0} \Phi(T) \quad (9)$$

In a numerical simulation that considers varying T , the pore RH must be estimated by use of Eq. (8) at each nodal point and at each time step. This estimation still requires the hydrothermic coefficient κ (Bažant and Najjar 1972). This

coefficient is always positive as the water content is known to decrease with T at constant RH . The dependence of κ on RH can be roughly evaluated by use of the non-linear relationship in Eq. (10) according to Bažant and Najjar (1972).

$$\kappa = 0.0135RH(1 - RH)/(1.25 - RH) \quad (10)$$

Coupled model procedure. Coupling the thermal- and moisture- transfer models to predict the pore RH through a slab requires the following procedures (coupled in series):

- (1) Predict the slab's temperatures around a specific year;
- (2) Provide an initial RH_{eq} profile through the slab;
- (3) Use the predicted temperatures and the previous time-step's RH_{eq} to compute the saturated moisture diffusivity D_T by use of Eqs.(7) and (9);
- (4) Input the D_T values (D_T is different through the slab's depth) into Eq. (2) and use the wetting and drying boundary conditions to simulate the RH_{eq} in the next step;
- (5) Use the predicted RH_{eq} to estimate the real RH using Eq. (8);
- (6) Repeat the steps from (3) to (5) to estimate the RH profile at all time steps.

Coupled model validation

First of all, the coupled model must verify whether the predicted slab temperatures can coincide with measured temperatures. To partially validate the coupled model, localized weather conditions including the wind speed, air temperature, and solar radiation for Rantoul, Illinois are used to predict slab temperatures of a concrete pavement test section at the Advanced Transportation Research and Engineering Laboratory (ATREL) run by the University of Illinois at Urbana-Champaign. Details of this test section can be found in (Kohler 2005). These verifications are conducted to validate predicted temperatures at depths of 1.27cm and 11.43 cm in comparison to measured values. As shown in Figure 2d and e, the prediction visually and statistically agrees with the observation.

The validation of the slab's internal RH is also conducted by inputting the predicted temperature to the moisture transport model as described previously. Meteorological data, including ambient RH and wind speeds, in Rantoul is used to compute the wetting and drying condition at this site. The initial RH within the slab is assumed to be 100% uniformly at the time of casting. Due to the use of fly ash in the concrete mix, an equivalent reduced water-to-cement ratio of 0.32 was used to simulate the moisture diffusivity the slab (Kohler 2005).

The predicted slab's internal RH agrees with the observations as well. In Figure 3, the embedded graph manifests that the variation of the predicted RH coincides with the prediction as corroborated by the statistical parameters. The use of a coupled model helps capture the daily cyclic change in internal RH , whereas an isothermal moisture prediction model could not. This coupled approach can help better predict moisture profiles that lead to moisture warping and differential drying shrinkage in concrete pavement slabs.

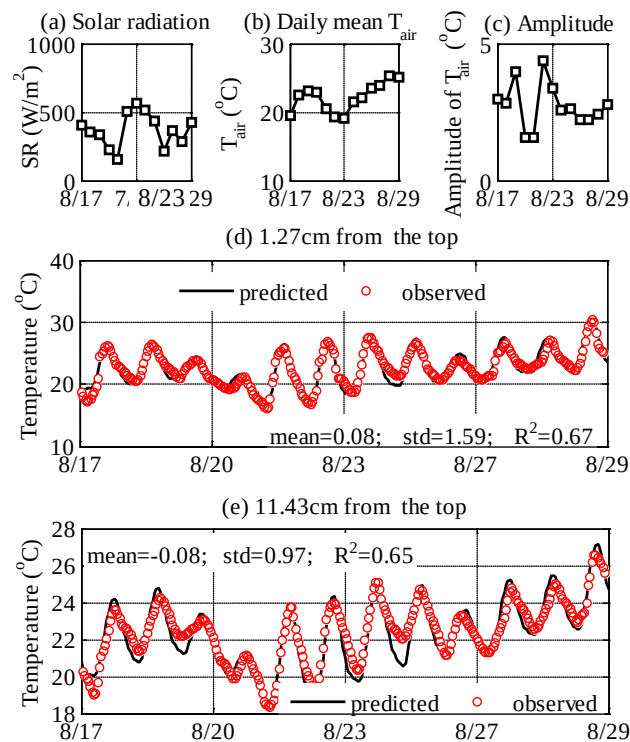


Figure 2. Verification of the example slab temperature prediction model.

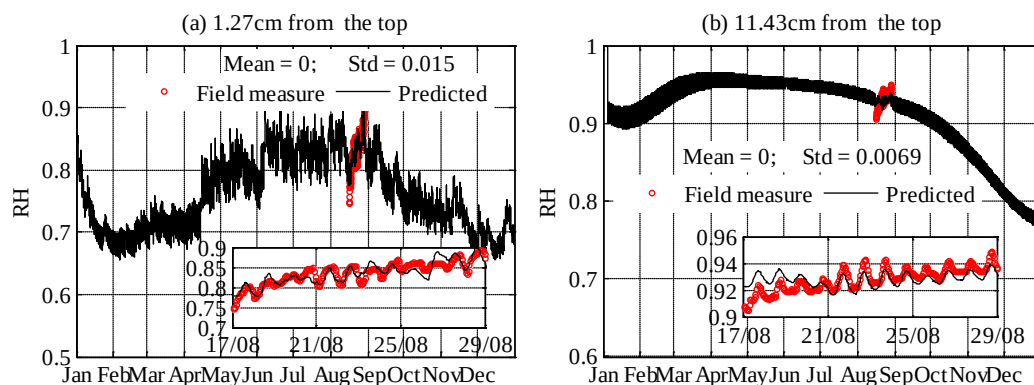


Figure 3. Field observation of internal RH and the predicted values by the use of coupled thermal transfer and moisture transport model.

Coupled Temperature-Moisture Sensitivity Study

The following sections investigate the influences of local weather conditions on the internal slab-RH distributions. For jointed concrete pavements, moisture warping and differential drying shrinkage play a key role in stress development and pavement performance in arid regions. To this aim, this study simulates the RH distribution of concrete slabs in the dry climate of Reno, Nevada, in the Western USA. The internal RH of a concrete slab in Reno is compared to the same slab under Los Angeles (LA), California, USA weather conditions in order to study the impact of localized climatic factors on a slab's internal moisture distribution.

The reason for this comparison of Reno and LA is due to the discernible seasonal weather conditions in these two regions based on the U.S. National Oceanic and Atmospheric Administration (NOAA) climate data. First, Reno's rainfall distribution is more uniform than in LA, whereas the seasonal total rainfall amount in both regions is almost the same as seen in Figure 4a. Secondly, the total number of rain events in both regions are roughly the same. Finally, both wind speed and

seasonal air RH in Reno is consistently lower than those in LA (Figure 4b,c) to provide some distinct differences for comparison between the sites.

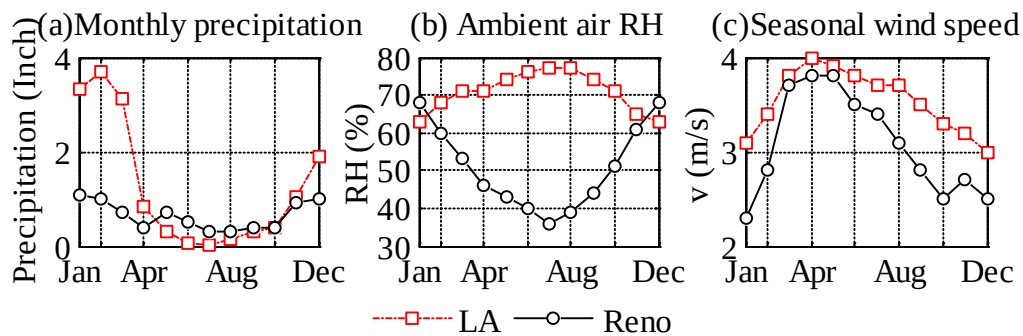


Figure 4. Rainfall distribution, air RH, and wind speed in Reno and Los Angeles.

The subsequent simulations use the following parameters, unless otherwise noted:

- Monthly precipitation distribution from Reno climate.
- Ambient air RH and local wind speed from Reno. During a specific day, the local wind speed and RH are regarded as constants.
- The w/c ratio of the 25.4 cm slab is assumed to be 0.45. Other parameters for the diffusivity including $\alpha_0 = 0.10$, $n = 6$, and $RH_c = 0.75$ are utilized.
- The solar radiation and air temperature as described in (Qin 2011) are used to simulated in-service slab temperatures.

Five-year simulations of the coupled thermal and moisture model are conducted to examine the evolution of the slab RH, beginning at the end of the curing, assumed to terminate at the end of June. The initial RH through the slab at this time is uniformly 100%. Usually, the moisture profiles at the half-simulation time (December 30, 2nd year) and full-simulation time (June 30, 5th year) are plotted in order to examine the difference between the predictions using different climatic boundary conditions.

The distinctive weather conditions of both regions lead to remarkably different moisture distributions within the slabs through a five-year simulation as shown in Figure 5. The slab in Reno demonstrates a lower relative humidity than the slab in LA. Notable differences in moisture between the climates are noted near the surface (Figure 5c) and deeper in the slab (Figure 5d and e). This infers that the external weather conditions influence not only the surface moisture, but the entire moisture profile of the slab.

However, since all the weather factors including rainfall distribution, wind speed, and air RH are different in both regions, the impact of each of these individual factors on slab-RH distribution cannot be determined. Therefore, an analysis to separate these factors necessitates.

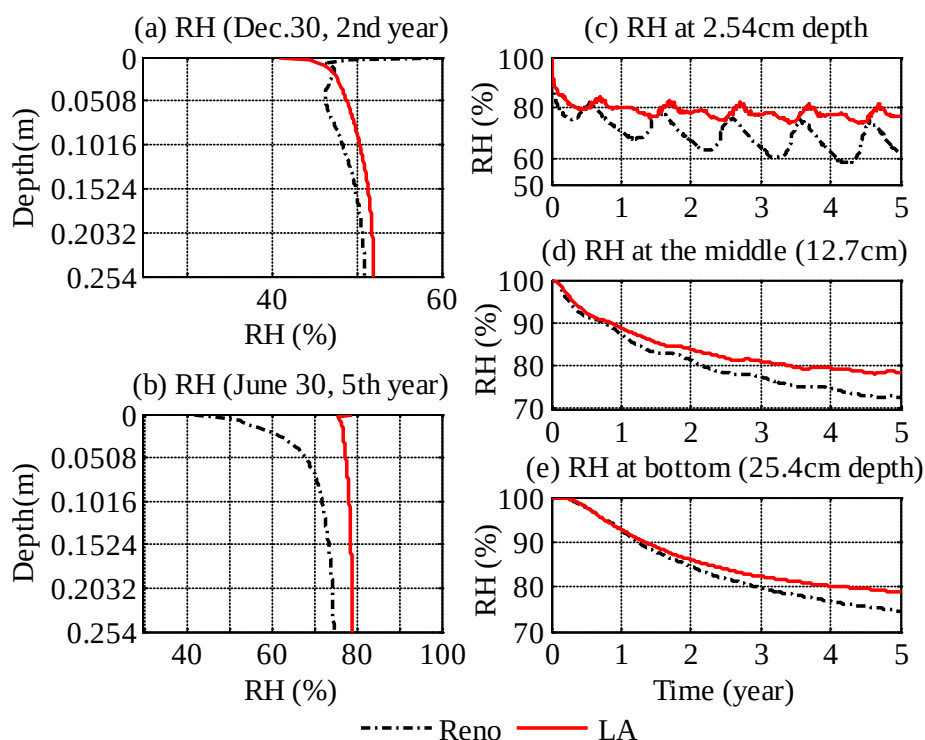


Figure 5. Predicted RH distributions in slabs in Reno and LA with time and depth.

Impact of rainfall. To assess the impact of the rainfall distribution on the slab-moisture distribution, the rainfall distribution of LA is entered into the coupled model with all the other weather conditions from Reno. This modified “LA rainfall pattern” can then be compared to the model predictions for an unchanged Reno climate, in order to assess the impact of a different seasonal rainfall on the model predictions.

The rainfall distribution does show some small influence on the near surface moisture distribution (Figure 6c), but shows little impact on the deep-slab moisture. The near-surface RH difference is partially due to the contrasting rainfall distribution of the two regions. However, at a closer look, it is primarily due to the probabilistic factors of local rain events resulting in a different rain duration and rain intensity. That is, even if the same rain distribution is used, rain occurring during a specific hour in the previous year does not necessarily indicate that rain would happen during the same time in the next year. Despite these probabilistic-induced deviations, a statistical mean difference between the two predictions is 5%, demonstrating that the rainfall pattern does not appreciably affect the predicted moisture profile of concrete pavement slabs.

Although the seasonal rainfall distribution does not affect slab moisture discernibly, the annual rainfall amount may greatly influence slab-moisture distributions. To investigate this issue, the study compares the RH distribution of the slab in Reno to the predicted RH distribution of a slab that is assumed to be in Reno, but sheltered from rain (zero wetting cycles). This comparison illustrates that the slab would have less pore moisture if there was not wetting cycles on the pavement surface as shown in Figure 7. Furthermore, greater deviation appears during winter time (0.5 year, 1.5 year, etc) as this time period signifies a slightly rainy season for Reno (Figure 4a). This infers that the occurrence of wetting events greatly influences the slab’s moisture budget. This influence is also reflected in the statistical analysis illustrated in Figure 7. The analysis demonstrates that when the wetting cycles go

unaccounted for, an underestimation in the RH of the entire slab occurs; thereby creating a clear bias and increasing the standard deviation to 2.8% (Figure 7d). Therefore, the annual rainfall amount significantly affects the moisture distribution of in-service slabs.

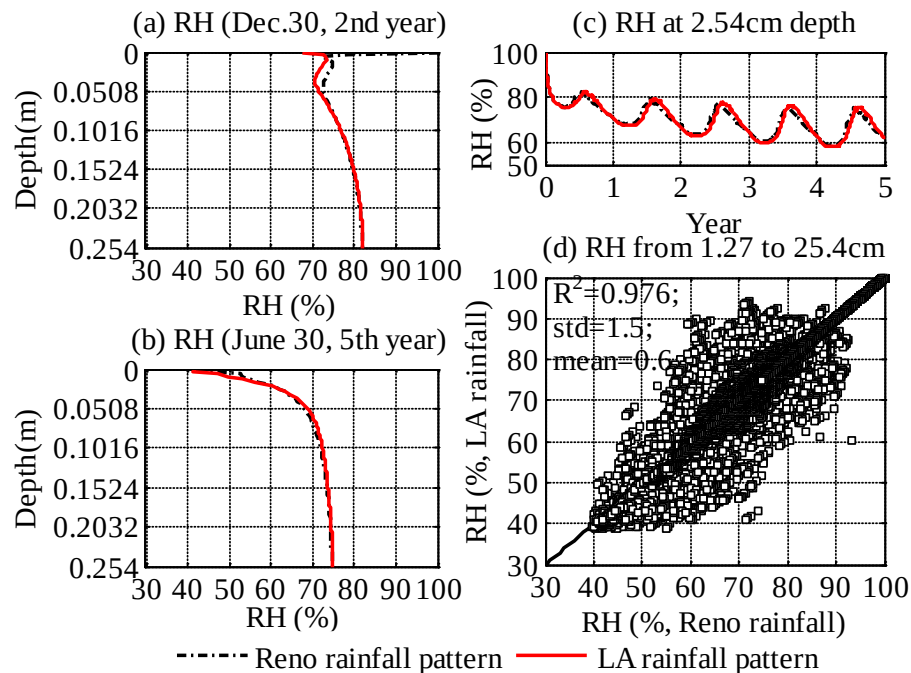


Figure 6. Impact of seasonal rainfall pattern on the moisture distribution of slab.

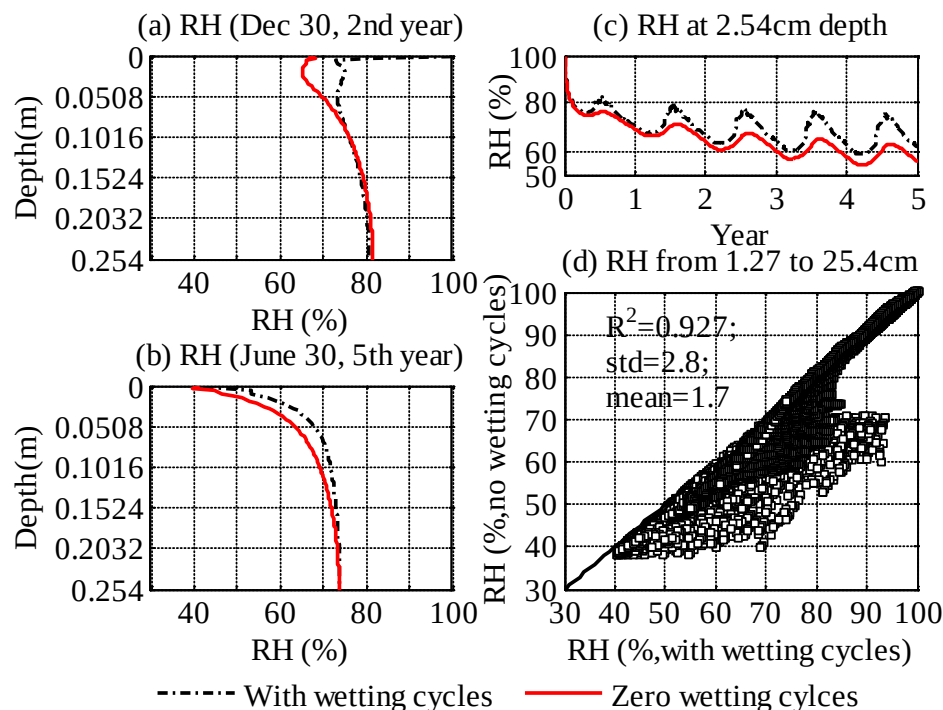


Figure 7. Effect of wetting cycles on moisture profiles in a concrete slab.

The nonlinearity of the concrete's diffusivity (as shown in Eq. 3) results in the slab RH being easily influenced by the wetting cycles, although the measure of the

wetting time is one-order of magnitude lower than that of the drying time. During the wetting cycles, absorption and permeability dominate the moisture intake. Capillary force also makes the concrete surface rapidly absorb free water at the surface. The moisture transport during these wetting cycles is thus significantly higher than the water vapor migration during the subsequent drying cycle. During drying cycles, the concrete surface rapidly becomes dry whereas the concrete below the surface is still wet. Drying of the surface results in a relatively lower diffusivity at the surface, thereby reducing the surface's diffusivity and blocking the rapid evaporation of the moisture absorbed at greater depths. In other words, concrete easily absorbs moisture when wetting but does not lose it when drying as easily. This phenomenon of the diffusivity leads to the wetting cycles greatly affecting the moisture budget within of slabs even if only accounting for a small probability of occurrence (e.g., approximately 180/8760 hours per year, or rain in 2% of the hours over a given year in Reno).

Impact of wind speed. To assess the impact of wind speed on the predicted moisture distribution, a similar exercise is performed where the measured wind speed for LA is substituted for Reno wind speeds while all other factors are still indicative of the Reno climate. Doing this, it was found that seasonal wind speed plays a negligible role on the slab-moisture distribution (Figure 8). This is true even though the mean monthly wind velocity in LA is always 0.2-1.0m/s greater than the wind speeds in Reno. Overlaps of the RH profile in Figure 8a (winter day) and b (summer day) verify the insignificant role of the seasonal wind speed on an in-service slab's moisture distribution. Unlike the deviation of the near-surface RH illustrated in Figure 6 when substituting rainfall patterns, two RH series at 2.54cm depth (Figure 8c) exhibit extremely high agreement when wind speed is exchanged in the model. The statistical analysis showing excellent agreement between the two swapped wind speeds (Figure 8d) further suggests that the seasonal wind speed pattern plays only a minimal effect on the internal moisture within a concrete slab.

The negligible role of seasonal wind speed on the slab-moisture profile may further imply that the daily variation of the wind speed works as a secondary role as well. To confirm this assumption, a random number is specified to the daily wind speed according to a standard normal distribution. Use of this random number does not alter the monthly average wind speed, but varies the wind speed at any specific time.

The predicted results indicate that the daily wind speed notably influences near-surface RH in some cases, but does not affect the RH at greater depths. As illustrated in Figure 9a, the predicted RH sparingly deviates from the line of equality when the RH at all depths of the slab is considered, inferring the impact of the daily wind speed variation. However, a truncated look at of the RH from depths of 1.27cm to 25.4cm (Figure 9b) yields regression coefficient of 0.9996; 0.1% standard deviation of the difference between the two predictions; and 0.9% maximum deviation of RH between these two predictions. Therefore, hourly wind speed does affect the near-surface moisture content (less than 1.27cm), but does not significantly influence the moisture budget at greater depths.

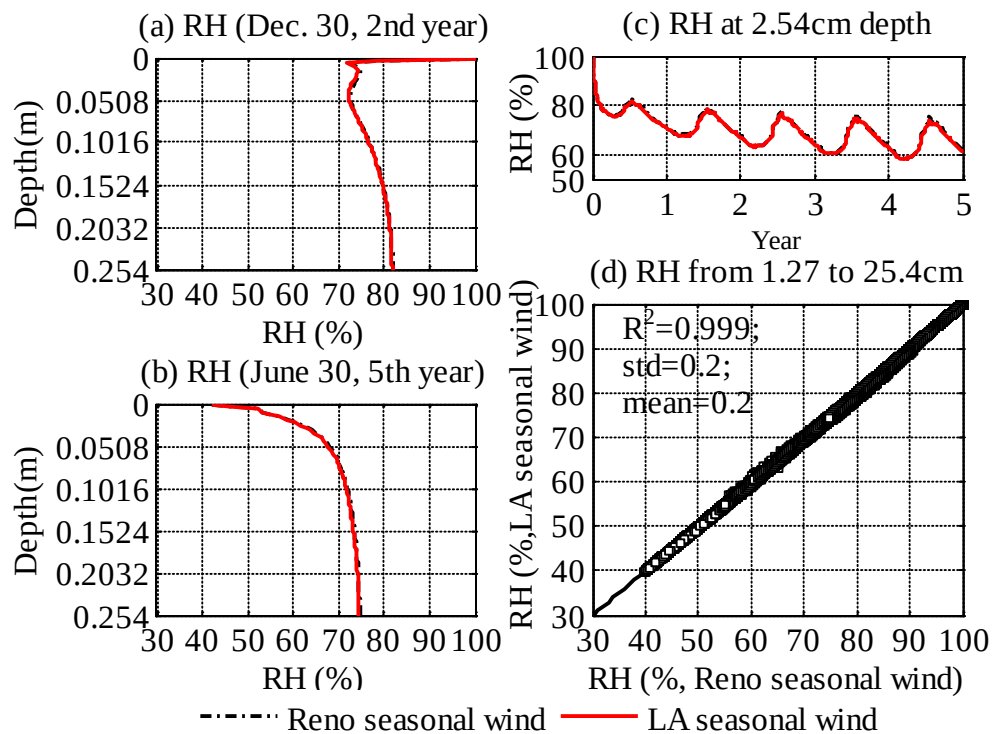


Figure 8. Impact of the seasonal wind speeds on the slab-RH distributions.

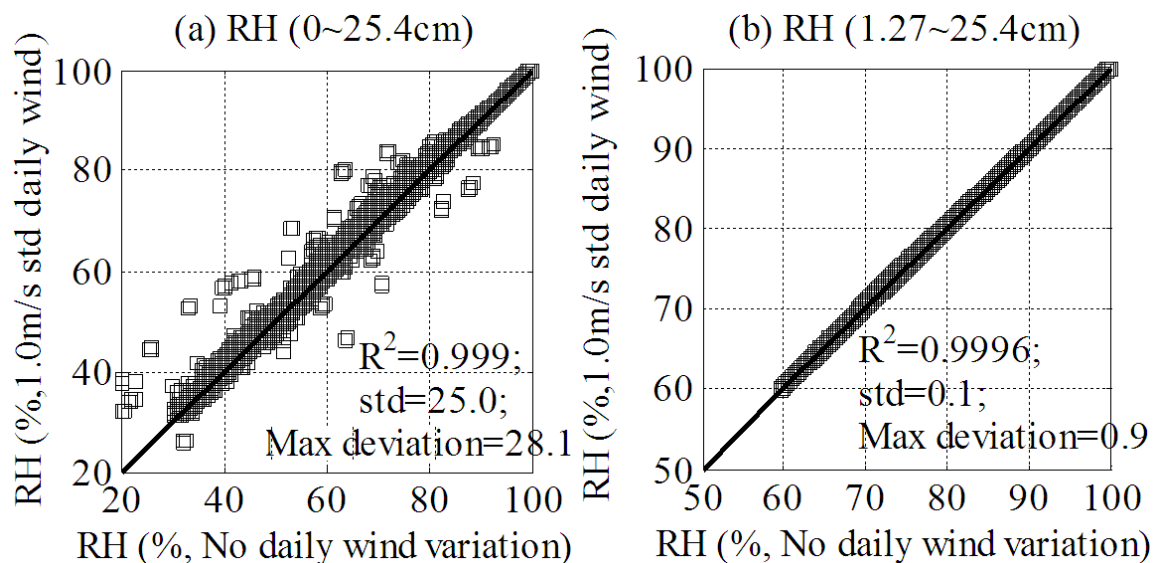


Figure 9. Impact of daily wind variation on the slab-RH distributions.

Impact of the ambient air RH. The seasonal ambient air RH appreciably controls the moisture distribution within in-service concrete slabs as shown in Figure 10. Data labeled with “LA seasonal air RH” are from the simulation that adopts all the weather parameters in Reno except the seasonal air RH, which is supplanted by the seasonal air RH in LA. Comparison of the simulated results distinguishes the difference between the predicted RHs of these two slabs. The plotted moisture profiles at both December 30, 2nd year and June 30, 5th year exhibit significant differences when compared with the data plotted in Figure 6 or Figure 8. These differences infer that the seasonal air RH is the primary factor in determining the moisture distributions through in-service concrete slabs.

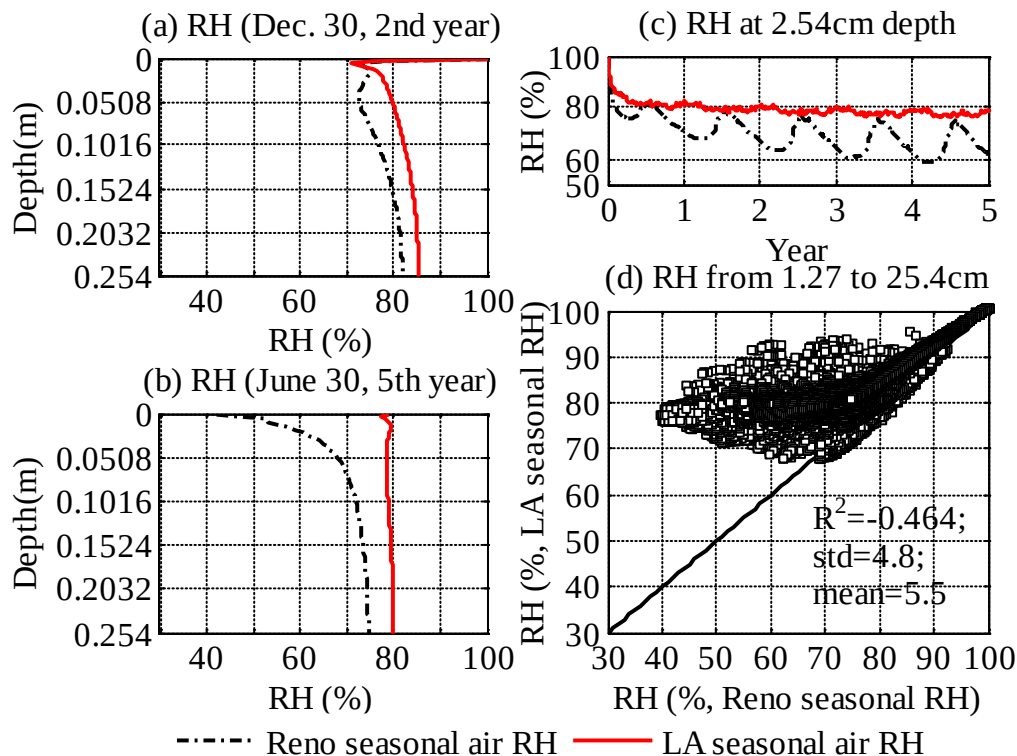


Figure 10. Impact of the seasonal air RH on the RH within in-service slabs.

This determination also can be seen from the similarity between the seasonal near-surface RH and the seasonal air RH. A relatively large difference between the near-surface internal RHs of these two simulations takes place in the summer months in every simulation year (Figure 10c), coinciding with the large difference in ambient RH between Reno and LA as shown earlier in Figure 4b.

Although the seasonal ambient RH plays a primary role on the internal RH within a slab, moisture within the slab is not distinctly influenced by the daily variation of ambient air RH. In this study, a sinusoidal wave of amplitude 8% is utilized for daily air-RH variation to approximate the monitored ambient air RH for the Reno airport from the NOAA database. Adoption of this amplitude in the predicted model results in a band-shape deviation along the line of equality, with a standard deviation of 0.41% and maximum deviation of 6.97% (Figure 11a). A truncated comparison (Figure 11b) focusing on the RH values from 1.27 to 25.4cm depth exhibits a better agreement. Therefore, while the daily variation of the air RH can slightly affects the near surface RH, the moisture budget at greater depths is nearly unaffected by daily ambient RH cycles between morning and afternoon.

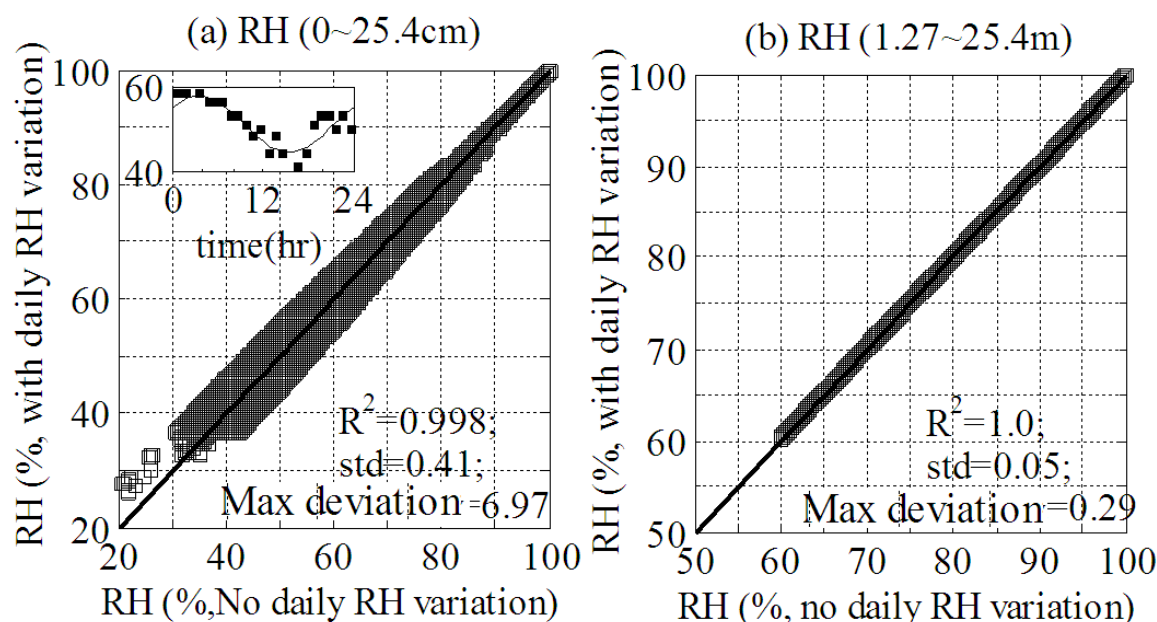


Figure 11. Impact of the daily air RH variation on the RH distribution within slabs.

Seasonal ambient RH controls the moisture convection at the slab surface and thus determines the slab-moisture budget. After the curing terminates or a wetting event ends, the slab surface has a greater RH than the ambient air, thereby allowing moisture to escape from the surface to the air. However, this moisture outflow cannot be maintained at a constant; otherwise the moisture within the slab will be rapidly depleted to 0. That is, the moisture exchange will eventually move toward a state in which moisture inflow roughly balances moisture outflow. At such a state, the wetting process leads to moisture gain and the drying events result in moisture loss. The data plotted from Figure 5 to Figure 10 indicate that the time from the end of the curing to such a stable state lasts a period of 5 or more years. This lengthy period means that after a specific wetting event terminates, the moisture outflow must follow an exponential decline and then become negligible; otherwise, the stable state will be quickly achieved. This interval of the exponential decline has been suggested to last 3-5 hours (Hover 2006; Al-Fadhala and Hover 2001). As the moisture diffusion within a slab is a boundary-value problem, this control infers that ambient RH dominates the resulting internal RH profile as the drying period is typically one-order of magnitude greater than wetting period. Therefore, seasonal ambient air RH dictates the moisture distribution within in-service concrete slabs.

Conclusions

A one-dimensional coupled heat and moisture transfer model was developed to better understand and predict thermal and moisture effects of in-service concrete pavement slabs. By coupling the thermal model and moisture model in series, the effects of daily changes in temperature on the internal RH were better captured. Using a non-linear moisture diffusivity model also helped better depict the moisture movement internally of a concrete slab.

Using this coupled model, simulations were conducted to better assess the variables that most affect the internal RH profiles on concrete slabs in Reno and LA. It was found that seasonal ambient air RH dominates the in-service slab-moisture distributions, whereas the daily air-RH variation only affects the near-surface internal

RH. While concrete easily absorbs moisture when wetting, but it typically loses water at a much slower rate due to the non-linearity of moisture diffusivity. Therefore, the annual rainfall amount significantly influences the slab moisture budget; but the effect of seasonal distribution of this rainfall is minimal. Daily variation of the local wind speed may notably affect the near-surface internal RH as this helps accelerate the escape of water immediately after a wetting event ends. However, the seasonal wind speed plays only a relatively negligible role in the internal RH distribution.

By understanding the factors which most affect the internal RH profiles of concrete slabs, better characterization of those primary factors can be accomplished. Ultimately, these more accurate characterizations of concrete's internal RH profiles can provide a better prediction of stress distribution and its subsequent affects on jointed concrete pavement performance.

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