UDC 625.717.02

O.V. Rodchenko, PhD
(National Aviation University, Ukraine)

Sensitivity quantification of airfield rigid pavement stress responses under impact of Boeing 737-10

This study evaluated the sensitivity of rigid pavement responses. The analysis was performed by positioning a Boeing 737-10 (B737-10) airplane at different locations (edge and corner of the concrete slab) as baseline while varying other initial data, such as mechanical properties of pavement structural layers and temperature variations.

In Ukraine, airfield rigid pavement is two-layer pavement structure. The improvement of the rigid pavement design is important when pavement is under action of the landing gears of new airplanes.

The purpose of research is to quantify sensitivity of stress outputs to various inputs required in airport rigid pavement design for Boeing 737-10 airplane.

A research version of the “Aerodrome 380” design software [2] has been developed, in which the airport rigid pavement is under action of wheel and temperature loading [5]. “Aerodrom 380” program uses a fatigue failure concept [1].

Investigations performed by A. Rezaei-Tarahomi et al. [4,6] include the use of different cases of rigid pavement structure, different loading conditions and locations for airplane Boeing 777-300ER. These investigations [6] reported that all stresses have sensitivity to concrete slab thickness.

The analysis has been performed for pavement structure by applying a B737-10 aircraft wheel loading. A four-layered airfield rigid pavement with 7,5 m concrete slab was modelled.

Inputs that are needed can be categorized as:

- pavement structure inputs;
- subgrade inputs;
- loading inputs,
- temperature values.

A detailed summary of the inputs are shown in Table 1.

To present the sensitivity of each input, a normalized sensitivity index (NSI) has been adopted [4].

Temperature loading related input exhibits sensitivity for top tensile stress. Concrete slab thickness exhibited the highest NSI for top and bottom tensile stresses in mechanical loading only case for the B737-10 main wing landing gear located at the corner of the concrete slab. Lean concrete and cement treated base thicknesses have high NSI for top tensile stresses but low NSI for bottom tensile stresses, while concrete modulus is effective input for both types of tensile stresses. Lean concrete modulus, treated subbase modulus have the lowest NSI for all stress responses.

Table 2 shows the sensitivity analysis results for different inputs. Concrete slab thickness is the most effective input for top and bottom tensile stresses. Top tensile stresses, unlike the bottom tensile stresses, exhibit significant sensitivity to the lean concrete and subbase thickness. Variations in modulus of concrete and subbase show less sensitivity index for bottom tensile stresses.

Table 1.

Ranges of inputs for sensitivity analysis

inputs category	inputs		min	baseline	max	base case
pavement structure inputs	concrete slab	elastic modulus, MPa	32400	35300	35300	32400
		thickness, m	0,34	0,4	0,45	0,4
		Poisson ratio	0,15	0,15	0,15	0,15
	lean concrete	elastic modulus, MPa	13000	17000	26000	17000
		thickness, m	0,20	0,25	0,30	0,25
		Poisson ratio	0,15	0,15	0,15	0,15
	cement treated subbase	elastic modulus, MPa	1950	4810	7800	7800
		thickness, m	0,15	0,20	0,25	0,15
		Poisson ratio	0,15	0,15	0,15	0,15
subgrade inputs	subgrade	subgrade ratio, MN/m^3	40	50	60	40
aircraft inputs	airplane B737-10 parameters	ramp weight, t	89,992			
		number of main gears	2			
		maximum load, t	42,492			
		tire pressure, MPa	1,62			
loading inputs	loading	loading position	concret slab edge / corner			
		daily average amplitude of temperature (July), ˚C [3]	9,4	10,2	11,2	9,4

Table 2.

Inputs ranking for stress responses

inputs	NSI top tensile stress	inputs	NSI bottom tensile stress
concrete slab thickness	1,784	concrete slab thickness	2,036
daily average amplitude of temperature	0,835	concrete slab modulus	0,591
concrete slab modulus	0,567	daily average amplitude of temperature	0,340
lean concrete thickness	0,562	lean concrete thickness	0,322
treated base thickness	0,338	treated base thickness	0,162
subgrade ratio	0,165	subgrade ratio	0,157
lean concrete elastic modulus	0,112	lean concrete elastic modulus	0,107
treated base elastic modulus	0,017	treated base modulus	0,016

The top tensile stresses exhibit considerable sensitivity to most inputs, but the bottom tensile stresses have considerable sensitivity to concrete slab thickness and concrete slab modulus. The stress responses are not sensitive to subbase modulus that coincide with conclusions of A. Rezaei-Tarahomi et al. [4].

For the top tensile stress, the thickness of pavement structural layers are the most effective inputs. It is noteworthy that subgrade modulus has a higher effect on top tensile stress.

Inputs ranking for top-to-bottom tensile stress ratio is follows: concrete slab thickness (1,957); daily average amplitude of temperature (0,495); slab modulus (0,025); lean concrete thickness (0,017); subbase thickness (0,009); subgrade ratio (0,008); lean concrete modulus (0,006); subbase modulus (0,001). Thus the top-to-bottom tensile stress ratio is sensitive to the concrete slab thickness and daily average amplitude of temperature, but it is not sensitive to the variation of subbase thickness, and the modulus of subbase that coincide with conclusions [4].

Conclusions

In the mechanical loading only concrete slab thickness, thickness of lean concrete layer and subgrade ratio are the most effective inputs.

In the modelling of mechanical and thermal loading case under corner loading condition, concrete slab thickness, among all other inputs, has the highest effect on top and bottom tensile stresses followed by concrete slab modulus and daily average amplitude of temperature.

The critical top-to-bottom tensile stress ratio is sensitive to the concrete slab thickness and daily average amplitude of temperature.

References

1. Advisory Circular 150/5320-6G. *Airport Pavement Design and Evaluation*, US Department of Transportation, Federal Aviation Administration, 2021. USA Standard. https://www.faa.gov/documentLibrary/media/ Advisory_Circular/150-5320-6G-Pavement-Design.pdf
2. Avtorske svidotstvo Ukraine. Computerna programa «Aerodrom 380» [Computer program "Aerodrome 380"] / Rodchenko O. V. (Ukraine). – № 57948 ; data reestratsiy. 30.12.14. [in Ukrainian].
3. DSTU-N B V.1.-27:2010 *Budivelna klimatologiya* [Construction Climatology]. Ukrainian Standard.
4. Rezaei-Tarahomi, A., Kaya, O., Ceylan, H., Gopalakrishnan, K., Kim, S., Brill, D.R. (2017). Sensitivity quantification of airport concrete pavement stress responses associated with top-down and bottom-up cracking. *International Journal of Pavement Research and Technology*, 10, 410–420. http://dx.doi.org/10.1016/j.ijprt.2017.07.001
5. Rodchenko, O. (2017). Computer technologies for concrete airfield pavement design. *Aviation*, 21(3), 111-117. https://doi.org/10.3846/16487788.2017.1379439
6. Tarahomi, A.R., Kaya, O., Ceylan, H., Gopalakrishnan, K., Sunghwan Kim, S., Brill, D.R. (2022). ANNFAA: artificial neural network-based tool for the analysis of Federal Aviation Administration's rigid pavement systems. *International Journal of Pavement Engineering*, 23:2, 400-413. https://doi.org/10.1080/10298436.2020.1748627