Study on improvement of design method for airport flexible pavement in Vietnam

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Abstract. Presently, there are 22 airports in operation comprising of 9 international airports and 13 domestic airports in Vietnam. According to the master plan of airports national wide, there are 124 airports and aerodromes both civil airports and military airfield. Design of airport flexible pavement is an important step during design the airport runway and taxi. Currently airport flexible pavement in Vietnam designs based on Vietnamese national standards, American standards and Russian standards. However, these standards have some issues such as design load, effect depth of the aircraft load, relative deflection caused by the aircraft and critical relative deflection. Therefore, this research points out improper issues that is not compatible with current practices of increase in airplane total weight. It also clarifies unfavorable effects of existing flexible pavement design method to the performance of runway pavement in some airports in Vietnam. Some technical measures are proposed for improvement of the current flexible pavement design standards and specifications are also recommended.

1. Introduction
Vietnam has 22 airports in operation comprising of nine international airports and 13 domestic airports. According to the master plan of airports national wide, there are 124 airports and aerodromes both civil airports and military airfields; of which, 28 dual-function airport for both civil and military, 96 military airports. The number of military airports need for new construction is 30, 76 airports and military airfields should be upgraded or rehabilitated in the coming time.
Regarding to airport pavement structures in operation, the sharing of asphalt concrete, composition structure of asphalt concrete and cement concrete, and cement concrete are 50%, 14% and 36%, respectively. Applying asphalt concrete pavement is a common trend due to its advantages such as: high strength, good riding comfort, low noise, no dust, good skid resistance, fast construction progress, as well as reasonable cost. Moreover, it is also quite convenient for maintenance, rehabilitation or upgrading. Therefore, asphalt pavement has become more proper application especially in case of airports in operation.
National standard coded TCVN 10907:2015 is the current standard for design of airport pavement. The standard is originated from Russian standard SNIP with less localization to actual conditions of airport operation in Vietnam. Therefore, there exists shortcomings in the standard as the result of less attention and limited investment on standardization. In some airports, there have occurred some damages on new repaired pavements by asphalt concrete or polymer modified asphalt such as rutting, deformation that affect safety operation of airplanes. The main causes of the damages have been identified that consist of design method, the effect of aircraft load, operation conditions, quality of construction materials, construction quality as well as maintenance performance [1]. Vietnam is a member of the International
Civil Aviation Organization (ICAO). The current aircraft fleet are mainly from Boeing and Airbus. Design of pavement structures of runways, taxiways, and aprons must comply with ICAO regulations and meet the requirements for the operation of the aircraft used by international airlines. Therefore, the research on the method of flexible airport pavement design in order to contribute for the improvement, supplementation to current design standards as well as propose new design method to meet the condition or operation of heavy commercial aircrafts with high frequencies would be in necessary in Vietnam. Therefore, in order to contribute for the improvement, supplementation to current design standards as well as propose some technical measures meet the condition or operation of heavy commercial aircrafts with high frequencies would be in necessary in Vietnam.

2. Some shortcomings of Vietnam standard

Vietnam standard TCVN 10907:2015 is compiled from CHIII standard from Russia with supplementation of provisions of the survey based on Advisory Circular - AC No 150 / 5320-6 [2]. When applying these standards during the design of airport pavements for heavy aircrafts with high operation frequency, the shortcomings are understood as follows.

2.1. Design load

Design load is requested to convert to design aircraft. Maximum weight of 85 tons tandem, 1.5 MPa tire pressure. Actual operation at airports with the B787-8 / 9, B777-300 / 200, B747-400 / 800, A350-900, A340, A330, A321,.... aircraft load and tire pressure are higher than the standard values (Figure 1). The load on the main gear of the aircraft in operation is much greater than the standard value. In pavement structural analysis, the total pavement thickness usually at least two times larger than the equivalent wheel path diameter, beyond the range in analysis nomogram.

![Figure 1. Comparison of air pressure of aircraft in operation with standard](image)

2.2. The effect depth of the aircraft load

The effect depth of the aircraft load is the thickness of the compressed soil layer as prescribed in Tables 6, 7 in TCVN 10907: 2015 varies from 5 meters to 6 meters depends on the load on one wheel of the main axle and consideration of soil property in the ground. For aircrafts with operation weight higher than the specified load in the standard, actual depth would be more than 6 meters depending on the load and bearing capacity of the ground. The depth needs being determined in order to consider for proper measures of treatment if necessary for improvement of the load bearing capacity.

2.3. Calculation of the relative deflection caused by the aircraft $\lambda_d$

The relative deflection caused by the aircraft’s load depends on the tire pressure $P_a$ and the elastic equivalent modulus $E_{ed}$ (overall elastic modulus) of the pavement and subgrade. Actual structural analysis for new aircraft with modulus of subgrade less than 45MPa, the total thickness of pavement layers is usually two times higher than the equivalent diameter of the aircraft wheel path that is out of
range of nomograph that helps to identify coefficient $\Psi_k$ \cite{1}. Therefore, it is impossible to identify $E_{ed}$ and relative deflection by aircraft load $\lambda_d$.

2.4. Calculation of the critical relative deflection $\lambda_o$

According to TCVN 10907:2015, critical relative deflection of pavement is determined based on the take-off frequency of aircraft per day (no more than 100 takeoffs per day), tire pressure (less than or equal 1.5 Mpa) and subgrade condition following nomograph 8G \cite{1}.

3. Proposal of technical measures to improvement the design of airport flexible pavement

3.1. Improvement of the Vietnam standard

In order to meet the actual conditions of airport operation, when applying TCVN 10907: 2015, it is necessary to study and supplement the following issues.

3.1.1. Determination of ground depth compressed under the effect of aircraft load

Application of finite element method to calculate the depth of effect of the load of the types of aircraft in operation. Condition determined by the finite element method is deformation or vertical displacement under the effect of the load $U \approx 0$ ($\varepsilon \approx 0$) or the load caused by the aircraft that is less than 5% of the load on the structural and ground layers itself. Based on the strain contour, displacement at the position of the displacement or deformation node to zero to determine the depth of effect of the load on the ground.

Analysis for Airbus, Boeing aircrafts with subgrade loading capacity in elastic modulus varies from 28MPa to 100MPa. Calculated results are presented as nomographs in Figure 2 and Figure 3.

![Figure 2](image2.png)

**Figure 2.** The depth of effect on the ground of the Boeing aircraft

![Figure 3](image3.png)

**Figure 3.** The depth of effect on the ground of the Airbus aircraft
The depth of effect of the payload of Boeing and Airbus aircrafts depends on the subgrade strength in elastic modulus or CBR value and the aircraft load; with subgrade elastic modulus of equal or less than 60MPa, the depth of effect of the type of aircraft is usually deeper than 6m. Nomograph in Figures 2 and 3 only apply for new airport pavements.

### 3.1.2. Calculate relative deflection when design load out of range of nomograph

When calculating the type of aircrafts with a heavy load and low load bearing capacity of subgrade, the total thickness of the large structure, $t_{tot}/D_e \geq 2$ using the empirical formula (1) proposed by Bacburg (Russia) as follows [3]:

$$\psi_k = \frac{1.05 E / E_{mt}}{(1 - E / E_{mt}) \sqrt{1 + 4 (t_{tot} / D_e)^2 (E / E_{mt})^{2/3}} + E / E_{mt}}$$

Where:
- $E_{mt1}, E_{mt2}, ... E_{mt}$ is the elastic modulus of material layers (MPa);
- $t_1, t_2, ... t_n$ is the thickness of structure layers (cm);
- $t_{tot}$ is the total thickness of the pavement structure (cm);
- $E$ is the elastic modulus of the existing ground (MPa);
- $D_e$ is the diameter of the circle (m) of the equivalent axle of the equivalent axle load.

### 3.1.3. Calculate the critical relative deflection when design load out of range of nomograph

The critical relative deflection of the pavement $\lambda_u$ depends on the type of soil, pressure on tires and number of times the conversion effect of $N_r$ of aircraft load. From the nomograph, the relation between the deflection $\lambda_u$ and the pressure on tires, frequency of aircraft operation is nonlinear. To make extrapolation for the case that design load out of range of the nomograph (in case $P_a > 1.5$Mpa, $N_r > 100$ passes / day), digitize the nomograph 8G in Excel, construct a regression function that determines the critical relative deflection following exponential rule on the Matlab software. The results of the regression functions are as follows:

- Clayey, clay, sandy (including laterite soil), determined by the formula:
  $$\lambda_u = \left[3.165 \left(-0.8395 p_u^2 + 3.208 p_u + 0.3722\right) \right] \times 10^{-3}$$
  (2)

- Dust sandy determined by the formula:
  $$\lambda_u = \left[3.163 \left(-0.9266 p_u^2 + 3.133 p_u + 0.0255\right) \right] \times 10^{-3}$$
  (3)

- Medium and large grain sand, determined by the formula:
  $$\lambda_u = \left[1.889 \left(-0.0702 p_u^2 + 1.793 p_u + 0.7897\right) \right] \times 10^{-3}$$
  (4)

The error calculated by regression formula and nomograph $\Delta \lambda_u < 1.79%$. According to the Russian Airport Design Guide [4], it is acceptable for the error of less than 10% in case of relative deflection, and error of less than 5% in case of flexural analysis for asphalt layers. Therefore, the error between the regression and nomograph of 1.79% is acceptable.

### 3.2. Modification and application of AC 150 / 5320-6 (2016) in Vietnam

Vietnam is a member of the International Civil Aviation Organization (ICAO). The current aircraft fleet are mainly from Boeing and Airbus. Design of pavement structures of runways, taxiways, and aprons must comply with ICAO regulations and meet the requirements for the operation of the aircraft used by...
international airlines. Therefore, it would be in necessary to improve and supplement to current design standards as well as propose some calculation methods to meet the condition or operation of heavy commercial aircrafts with high frequencies in Vietnam.

3.3. Concerned issues for application in Vietnam

This method is built based on natural conditions, materials, construction technologies of America. To apply in Vietnam, there should be researches, evaluation and adjustment for customization due to local conditions of geographical, natural conditions, materials, construction technology. Detailed regulations on materials, construction specification and acceptance of structural layers issued by FAA in standard AC 150 / 5370-10 (2014), standard construction and acceptance of the airport [4]. When applying design standards AC 150 / 5320-6F, it is necessary to compile AC150 / 5370-10 for consistent application in Vietnam as a basis for clearly defining construction material standards, test methods, construction technical guidelines and construction acceptance in construction of the flexible pavement of the airports. As the fact that Vietnam does not have separated standards in materials testing, construction and acceptance for airport pavement; standards of road pavements are referred.

4. Conclusions

In the short term, parallel use of Vietnam standard (TCVN 10907:2015) with some supplementation reasonable results from studies, and AC 150/5320-6 for comparison, verification and selection of thicker structure for more safety. After completion researches, analysis, and evaluation, new Vietnam standard should be promulgated for unified application.

In the long term, it is recommended to apply the standard AC 150 / 5320-6 to design pavement structures for airports and airfields in Vietnam. This is the standard recommended by the International Civil Aviation Organization (ICAO) with practical application in many countries. The Civil Aviation Administration of Vietnam is recommended to study and promulgate AC 150/5320-6 as in-house standard to apply with additional researches, adjustment taking into consideration of local conditions. Promulgation national standard for airport pavement design and its quality evaluation is also recommended.

Material investigation, design of asphalt mix that proper for conditions of high temperature of 600C and aircraft operation frequency of more than 100 operations/day at high air tire pressure up to 1.75MP for new construction of airports in Vietnam in the future.

Research, compile the set of standards on testing, construction and acceptance of airport pavement according to AC150 / 5370-10 (2014) for completion.

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