Improvement of methodology of calculation and assessment of transport and operational condition of airfield pavement (on the example of airport pavements of «Kyiv» and «Mykolaiv» international airports)

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Abstract. The article presents the results of assessment and forecasting of transport and operational condition of airfield pavements on the example of airfield pavements of Kyiv and Mykolaiv International Airports. Domestic and foreign methods of assessment of transport and operational condition and calculation of airfield pavements have been analyzed. One of the most common methods of qualitative assessment of the transport and operational condition of airfield pavements is the method , the essence of which is to compare the classification numbers of aircraft and the bearing capacity of the pavement at the same strength of the subgrade. The results of calculation and design of airfield pavements were performed on the example of Kyiv and Mykolaiv International Airports using the FAARFIELD program. An alternative design of flexible airfield pavement of Kyiv International Airport is proposed. The engineering and geological conditions of Kyiv International Airport were analyzed in detail. Visual investigation of the surface of the pavements of all elements of the airfield of Kyiv International Airport showed that they have satisfactory transport and operational condition. The classification numbers PCN of rigid airfield pavements of Kyiv and Mykolaiv International Airports and flexible airfield pavement of Kyiv International Airport have been calculated with the help of the FAARFIELD program. PCN of the offered design of a rigid airfield pavement of the «Mykolaiv» International Airport is PCN 70/R/C/W/T. This means that the aircraft of this element of the airfield can perform take-off and landing operations without restrictions. Likewise, aircraft can perform take-off and landing operations without restrictions on rigid and flexible airfield pavements of «Kyiv» International Airport.

Keywords: runway, transport and operational condition, airfield pavement, method of signal estimation, *ACN* - *PCN* method, reliability, pavement slabs.

Introduction

The choice of optimal solutions in the design of airfield pavement structures, both rigid and flexible, technologies for their manufacture, construction and operational control necessitates the widespread use of methods of mathematical analysis [7, 8, 19, 21]. Ensuring the reliability and durability of rigid types of airfield pavement is becoming increasingly important in connection with the mass construction and reconstruction of airports in Ukraine and the development of modern aircraft [9, 19]. Premature destruction of concrete and reinforced concrete structures of airfield pavements requires significant investment to strengthen them. The reasons for the premature destruction of rigid airfield pavements are the imperfection of the theory of calculation, which does not allow to fully take into account the real working conditions during operation, as well as, to some extent, the low culture of construction work performance [7, 8, 15, 19, 21, 22, 23]. Variety of soil and climatic conditions, differences in the work of individual structural layers of pavement, and a significant number of factors (temperature and humidity, statistical, acoustic and dynamic loads, vibration) require a very complex analysis in the selection and substantiation of the design of the airfield pavement [7, 8, 15, 16, 19, 21].

To determine the quantitative characteristics of the durability of rigid airfield pavements it is necessary to know the regularity of changing a complex of external and internal factors that determine the behavior of the structure over time. These factors include power factors – the load from the weight of the aircraft, the thermodynamic effects of gas flows, the effects of ambient temperature and other climatic factors. It is also necessary to take into account the elements of geometric schematization and the corresponding deflection of structures, anisotropy of physical and mechanical properties of materials used in the construction of airfield pavements. The actual construction parameters of airfield pavement structures are of great importance – these are the objective characteristics that are obtained during the construction of pavements.

During operation, airfield pavements are affected by repeated application of force loads. This change in time is significant not only for fast processes that are associated with dynamic loading but also for quasi-static loading processes, i.e. periodic changes in ambient temperature.

To determine the durability of the pavement structure, along with the above data, it is necessary to operate on the reliability characteristics that make up the pavement elements, the types of connections of these elements, and data on the impact of element failures on the reliability of the structure as a whole. Real constructions can be represented by analogues in the form of appropriate mathematical models [7, 8, 9, 15, 19, 21, 22, 23].

Ensuring long-term unfailing operation of rigid airfield pavements is associated with certain material costs, so when selecting and substantiating the design of airfield pavements taking into account the specified durability it is necessary to consider not only the cost of the designed pavement but also the cost-effectiveness of extension of service life of the corresponding design. Therefore, taking into account the above-mentioned, it is offered the experience of designing airfield pavements in the modern conditions of Ukraine on the example of the «Kyiv (Zhulyany)» International Airport and the «Mykolaiv» International Airport. Reasonable choice of design and airfield planning solutions will ensure the safety and comfort of takeoff and landing of aircraft [7, 8, 9, 15 , 16, 19, 21].

1. Assessment methods of the transport and operational condition and calculation of airfield pavement

Successful operation of airfield pavements depends on the condition of structural elements, proper organization of maintenance work, and design of airfield pavements. During operation, under the influence of aircraft loads and natural factors, there is physical deterioration of the surface of the pavement and internal force damage of the airfield structure, which reduces its load-bearing capacity and surface quality [7, 8, 9, 15, 16, 19, 21]. Preservation of the suitability of pavement is the main task of the airport. The rate of accumulation of damage in the pavement during operation is highly dependent on the rate of its overload. Reliability of airfield pavements is the probability of their unfailing work in a given period of operation. The realization of the reliability of the structure laid down in the design of airfield pavements is ensured by the concerted work of the main bearing layer, base course, and subgrade. The concept of durability is closely related to the reliability of the system. Durability is the time of operation of the system from the beginning of the operation to its failure. The relationship between reliability $p(\tau)$ and density distribution probability for durability $P(\tau)$ is determined by the formula:

$$p(\tau) = -\frac{P(\tau)}{d(\tau)}. \tag{1}$$

The main function of the «airfield pavement» system is to ensure the safe operation of aircraft. Impairment or loss of coverage of the ability to provide take-off and landing operations of aircraft is a failure. The reliability scheme of the «airfield pavement» system is determined by a group of interconnected elements «plate», «joint», «base», and «soil», each of which has its own probabilistic characteristics of unfailing operation. The probability of unfailing work of any element of the pavement is a function of failure rate and operating time. The main calculated indicators that make up the quality of the pavement are: strength and durability of raw materials; characteristics of design loads; working conditions of the structure. Each of the calculated indicators is characterized by a complex functional relationship of different characteristics that reflect the design, technological and operational properties.

As a mathematical basis for the analysis of reliability and durability of airfield rigid pavements, it is necessary to use statistical methods in building mechanics which have found practical application in the estimation of reliability of some engineering structures [7, 8, 15, 16, 9, 18, 19, 21].

The theory of reliability allows estimating statistical stress fields which arise in structures of airfield pavements at various combinations of loads and influences [9]. If the structure is loaded with a random load, then the movement of the structure is a random process. This motion can be described by the methods of correlation and spectral theories or by the theory of random processes of the Markov type. Using these methods, it will be possible to calculate the statistical characteristics of stresses that occur in the structure. Further growth comes to the determination of the reliability and durability of the structure. Thus, if the change in stress in the structure is a narrow stationary random process and the reason for failure – the accumulation of fatigue damage, the average durability can be determined by the formula:

$$\overline{T} = -\frac{T_{еф.}}{\int_0^\infty \frac{\rho(S)dS}{N(S)}}, \quad (2)$$

wher $\rho(S)$ – is the distribution density of probability for stress maxima; $N(S)$ – the equation of the fatigue curve, which connects the limit number of cycles with stress; $T_{еф.}$ – effective period of stress change.

The application of methods of reliability theory in structural mechanics requires the accumulation of statistical data for external loads and properties of applied materials of structures [9]. The application of these data requires advanced experimental research using the methods of mathematical statistics to process the results. Necessary statistical experimental data on the reliability of elements and structures of pavements can be obtained as follows: the results of operation; according to the results of tests; by modeling the operation processes of airfield pavements.

The greatest importance for the reliable operation of rigid airfield pavements is to consider the force factors of the effects of moving load and ambient temperature [16]. The system "man-made surface" on the runway, taxiway or parking position in its simplest form is a certain representation of the elements – plates, the failure of which is the loss of load-bearing capacity installed during operation or as a result of specially organized tests. The butt joint is "included" in the "paving slab" element, since failure (failure of butt joints) in all cases causes the paving slab failure. In the case where the failure of the pavement occurs in the condition of failure of any individual plate, there is a so-called serial connection of elements for reliability, which is defined by a well-known expression:

$$P = \prod_{i=1}^{n} P_{ел}^{i}, \quad (3)$$

where n – the number of plates in the airfield pavement.

Since the purpose of calculating the design of the airfield pavement is to obtain a guarantee that during the period of operation will not occur any of the unacceptable limit states, the strength condition will be written as follows:

$$S \le R, \quad (4)$$

where S – load, effort or stress in the plate from external forces; R – bearing capacity of the plate.

For today, airfield pavements continue to be in operation after a sufficient number of slabs were damaged.

One of the most common methods of qualitative assessment of the transport and operational condition of airfield pavements is the *ACN - PCN* method, the essence of which is to compare the classification numbers of aircraft and the bearing capacity of the pavement at the same strength of the subgrade. The classification number of airfield pavement shall not be lower than the classification number of the aircraft operated on the pavement:

$$K \cdot ACN \leq PCN \text{ ,} \tag{5}$$

where K – is the coefficient that takes into account the intensity of aircraft movement; ACN – aircraft classification number; PCN – pavement classification number [4, 5, 6, 10, 11, 12, 13, 14, 17, 24].

In practice, the following methods of estimation the transport and operational condition of airfield pavements are also widely used: methods of signal estimation; determination of the airfield pavement condition index; standard method for determining the pavement condition index PCI .

2. Assessment methods of the transport and operational condition and calculation of airfield pavement

Assessment of the suitability for further operation of rigid airfield pavement was performed on the example of «Kyiv (Zhulyany)» and «Mykolaiv» International Airports.

2.1 Results of calculation and design of airfield pavements on the example of «Kyiv (Zhulyany)» International Airport

During the research of physical and mechanical characteristics of the subgrades of the airfield pavements, natural and soil-geological conditions of the Kyiv (Zhulyany) airport location area were studied and taken into account. It was stated that the climate of the territory, as well as the entire Kyiv region, belongs to the temperate-continental. The average air temperature for the year ranges from 6,6 to 7,2 ºC. The maximum temperature in summer is 37 - 39 ºC, the minimum in the coldest winters -36 ºC. The average long-term amount of precipitation is 550 mm with fluctuations over the years from 392 to 925 mm. The main number of which (about 75%) falls on the period from April to October.

The relative humidity is high and on average is 84% per year, decreasing to 73-60% in summer and rising to 91% in winter. This causes the evaporation of a relatively small amount of moisture from the soil surface, which with a significant amount of precipitation creates a positive balance of moisture in the soil. In general, the area belongs to the zone with moderate humidity and moderate warm climate.

The main source of soil moistening is rainwater. Due to insufficient surface water runoff and close location from the daily surface of groundwater (1,7 - 2,0 m), the airfield area, according to the existing road-climatic classification, should be classified as 2nd type of hydrogeological conditions (wet places with excessive moisture in certain periods of the year), the second road-climatic zone [20], or U-1 for the territory of Ukraine.

The upper part of the engineering geological cross-section consists of bulk soils, represented by sand with insignificant content of organic matter (humus 0,5 - 1,0%), as well as supra-moraine thickness of fine-grained and dusty sands of water-glacial origin of the Middle Quaternary period.

1. In the upper part of the engineering-geological cross-sections (up to a maximum depth of 5,2 m) on the entire area of the airfield there are only two engineering-geological elements (EGE):

- EGE-1 (upper layer of soil) — sandy loam with layers of coarse sandy loam, from gray to dark color and from hard to plastic consistency. Index of dry soil density: ρ_d = 1,58 – 1,62 g/cm3, porosity coefficient e = 0,65 – 0,70, natural soil humidity W = 12 – 24 %. Such soils can be singled out at the end section of taxiway-2, where they are well compacted at the subgrade of the pavements (ρ_d = 1,68 - 1,78 g / cm3, e = 0,50 - 0,60) and have mostly semi-solid and even solid consistency with natural humidity W = 17%;
- EGE-2 (lower, under EGE-1, soil layer) - fine-grained sand with layers of dusty sand, from light gray to yellow, water-saturated, high density with layers of medium density. Index of water saturation coefficient Sr = 0,8 - 1,0 and porosity coefficient e = 0,55.

2. Analysis of engineering geological research data shows that for these two types of soils (sandy loam and fine-grained sand) at the airfield of the «Kyiv (Zhulyany)» airport in the calculation of PCN classification numbers for all elements of the airfield it is possible to accept with sufficient justification the normative values of the coefficient of subgrade resistance Ks = 50 MN/m3 and Ks = 70 MN/m3 and the modulus of elasticity E = 37 MPa and E = 100 MPa respectively.

The geological structure of the site is composed of loams, sandy loams, sands and clays, which are covered with bulk soil and soil-vegetation layer [15].

According to engineering geological researches and laboratory analyzes at the site, the following engineering geological elements (EGE) have been identified:

EGE - 1. Bulk layer - brownish-gray loam, in places with content of construction debris up to 10%. With layers of sand, in places rubble with loamy aggregate (tH).

EGE - 2. Soil-vegetative layer – dark gray sandy loam, humus-rich, with grass roots, has solid consistency (bH).

EGE - 3. Dark gray sandy loam, humus-rich, with a solid consistency (bH).

EGE - 4. Yellowish-gray, pale yellow sandy loam, loess-like, non-sedimentary, consistency range from solid to plastic (vd PII-III).

EGE - 5. Grayish-yellow sand, fine, low-moisture, with medium density (vd PII-III).

EGE - 6. Brownish-yellow, light gray, light brown sandy loam, sandy, has from solid to plastic consistency (fPIIdn).

EGE - 7. Dark yellow, grayish-yellow sand, dusty, with layers of loam, with the inclusion of gravel and fine pebbles up to 10%, low moisture, dense (fPIIdn).

EGE - 8. Dark yellow, brownish-yellow sand, fine, loamy, with layers of sandy loam to the bottom, low-moisture, dense (fPIIdn).

EGE - 9. Light gray sand, fine, with thin layers of sandy loam, saturated with water, dense (fPIIdn).

EGE - 10. Brownish-gray, light brown loam, with the inclusion of gravel and carbonate concretions up to 10%, consistency range from semi-solid to low-plastic (fPIIdn).

EGE - 11. Brownish-gray, dark brown clay, with inclusions of carbonate concretions up to 5%, has semi-solid consistency (N2).

The master plan of «Kyiv (Zhulyany)» International Airport is shown in Fig. 1.

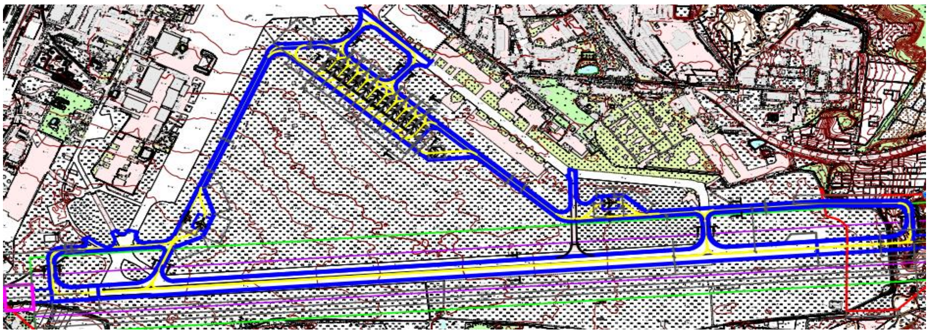


Fig. 1. The master plan of «Kyiv (Zhulyany)» International Airport.

The power, boundaries and conditions of engineering-geological elements are shown in the engineering-geological cross-section (see Fig. 2).

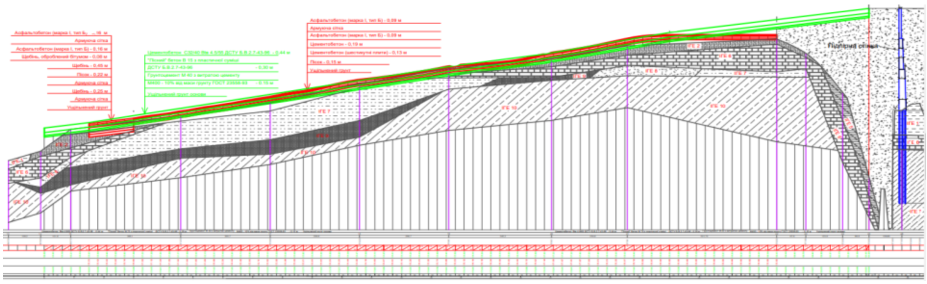


Fig. 2. Longitudinal profile along the axis of the runway of "Kyiv (Zhulyany)" International Airport.

According to the inspection materials and in accordance with the information at the airfield are located:

- rectangular runway: 2310x45,0 m;
- airfield class - B (4C);
- pavement - monolithic concrete, reinforced with asphalt concrete;
- the runway has a planned section of 75 m wide on both sides of the man-made runway surface and has a length of 2890 m;
- FATO (final approach and take-off area) is 90 m wide and long.

The width of the runway is 280 m (140 m from the axis in each direction).

It is planned to operate B737-9/BBJ MAX9 and A321/neo aircraft at the aerodrome.

It is foreseen that the size and configuration of the apron and long-term parking positions should provide:

- placement of the estimated number of operated types of aircraft, taking into account the designed intensity of their movement and cost-effectiveness of planning decisions;
- safe maneuvering of aircraft and the minimum length of their routes between the runway and the parking positions on the apron and long-term parking positions;

- safe and convenient passage, placement and maneuvering of special vehicles and mechanization means;
- safe passage of passengers on the shortest routes between the air passenger terminal and aircraft parking positions;
- placement of stationary equipment for aircraft maintenance at the parking positions;
- processability of construction of pavements of apron and long-term parking positions of aircraft;
- the possibility of mechanized cleaning of the apron surface and long-term parking positions of aircraft from snow and ice, as well as mechanized collection of garbage and foreign objects;
- the possibility of expanding the area, taking into account the prospects of increasing traffic;
- appropriate sanitary and hygienic conditions and convenience in the location of the service and technical area of the airport.

Visual inspection of the surface of the pavements of all elements of the aerodrome showed that they have a satisfactory transport and operational condition. This is due to the fact that in 2008 and 2009 almost all pavements of «Kyiv (Zhulyany)» airfield were reinforced with structural layers of asphalt concrete. In addition, the existing runway was extended by 150 m by building a new flexible asphalt concrete pavement on this section, as well as on the part of taxiway-1 adjacent to the runway.

The designs of pavements and layer thicknesses were accepted according to the data carried out by the method of drilling test wells. The layer composition of the airfield pavement structures of Kyiv (Zhulyany) International Airport is shown in Table 1.

The actual thicknesses of the pavement layers were determined by means of averaging the thicknesses measured after bore core cutting-out and wake pitting of the pavements. These thicknesses of artificial bases of coatings are accepted according to documentary data because determining the actual thickness of the layer of sand and gravel does not provide the accepted accuracy (these materials have the ability to partially displace the underlying soil during long-term operation of the coating).

On the coatings that were subject to amplification, the special alignment layers with asphalt concrete with a minimum thickness of 2 cm were laid.

Therefore, considering the above mentioned, 2 variants of the design of the artificial runway coating (Fig. 3, 4) are offered. The artificial pavement constructions are defined based on: climatic, hydrogeological, and soil conditions; features of the influence of the code C aircraft coverage, which are operated in these areas; availability and possibility of using local building materials.

The designed runway pavement construction is designed for loading from aircrafts B737-9/BBJ MAX9 and A321/neo and consists of: compressed soil; stabilized soil that is stabilized by cement to M40, h=0,15 m; lightweight concrete B15, h=0,30 m; cement concrete C32/40 Btb 4,5/55, h=0,45 m.

The dimensions of cement-concrete slabs are 7.5x7.5.

The stabilized roadsides have a construction: compressed soil; sand-cement M40, h=0,20 m; cement concrete C32/40 Btb 4,5/55, h=0,26 m.

The coating is designed for loading from aircrafts B737-9/BBJ MAX9 and A321/neo, the technical characteristics of which are shown in Table 2 and Fig. 5-6.

Table 1. International Airport «Kyiv (Zhulyany)» Pavement Constructions.

Airfield Element	Pavement Construction	Actual Pavement Thickness, cm
1	2	3
Runway (PK0–PK1+50)	Asphalt Concrete (brand I, type B) Reinforcing Mesh Asphalt Concrete (brand I, type B) Gravel Processed by Bitumen Gravel Sand Reinforcing Mesh Gravel Reinforcing Mesh Compressed Soil	16 16 8 45 22 25
Runway (PK1+50–PK19+50)	Asphalt Concrete (brand I, type B) Reinforcing Mesh Asphalt Concrete (brand I, type B) Cement Concrete Cement Concrete (hexagonal slabs) Sand Compressed Soil	9 9 19 13 15
Runway (PK19+50–PK23+10)	Asphalt Concrete (brand I, type B) Reinforcing Mesh Asphalt Concrete (brand I, type B) Slabs ASP-18 Sand-Cement Compressed Soil	9 9 18 15

Thus: **for aircraft B737-9/BBJ MAX9:** basic load on the main gear $F_n = 408{,}3758\ \kappa H$; the number of wheels on the main gear $n_k = 2$; distance between the centers of tires footprints of the main gear $a = 0{,}86\ \text{м}$; the number of the axis on the main gear $n_a = 1$; the inflation pressure into the main gear tires $p_a = 1{,}59\ M\Pi a$.

for aircraft A321/neo:
basic load on the main gear $F_n = 453{,}544\ \kappa H$; the number of wheels on the main gear $n_k = 2$; distance between the centers of tires footprints of the main gear $a = 0{,}927\ \text{м}$; the number of the axis on the main gear $n_a = 1$; the inflation pressure into the main gear tires $p_a = 1{,}57\ M\Pi a$.

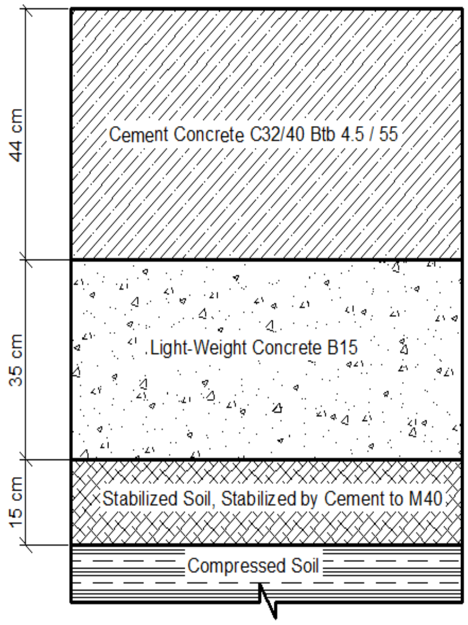


Fig. 3. Variant 2 of International Airport «Kyiv (Zhulyany)» Artificial Pavement Construction.

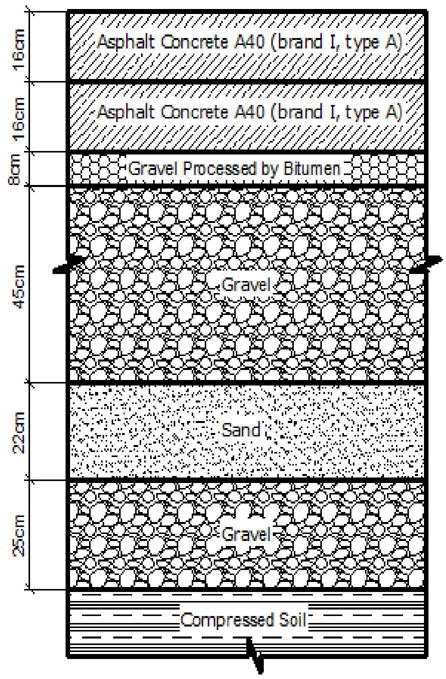
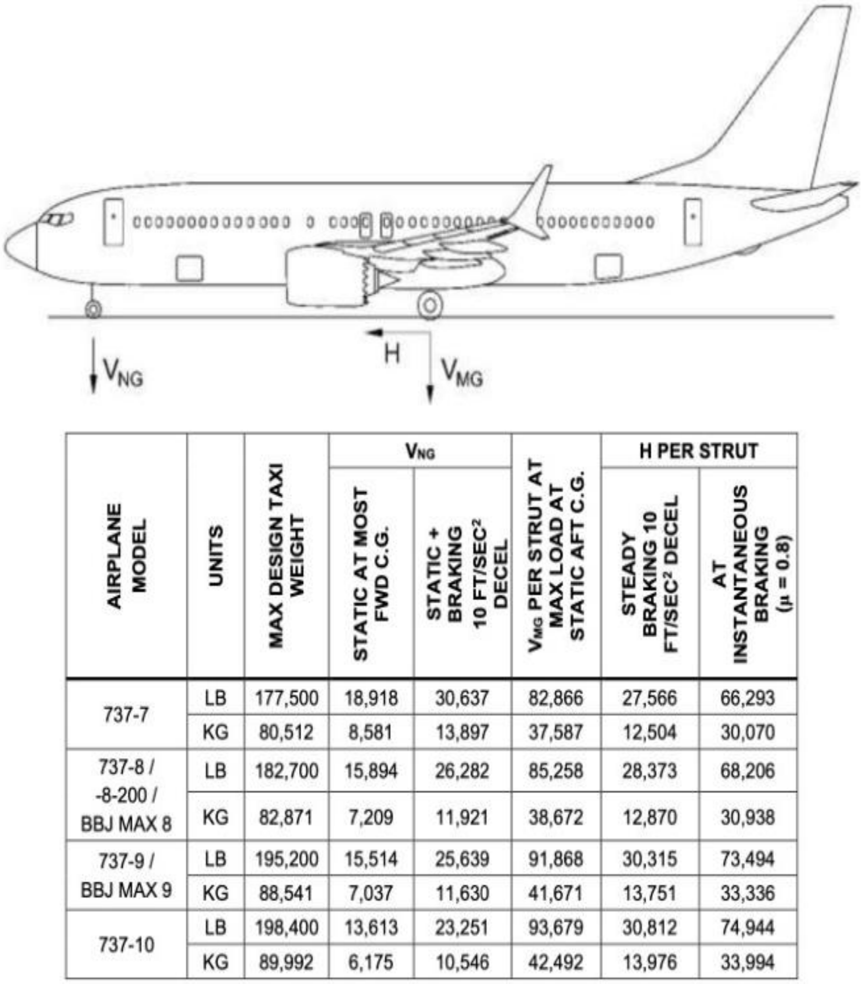


Fig. 4. Variant 2 of International Airport «Kyiv (Zhulyany)» Artificial Pavement Construction.

Table 2. Technical Characteristics of Aircrafts B737-9/BBJ MAX9 and A321/neo.

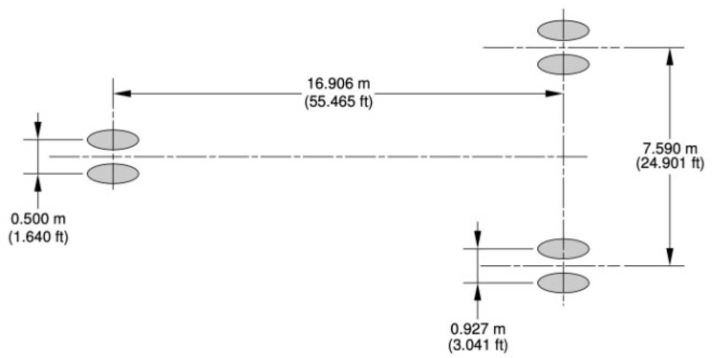
Aircraft	B737-9/BBJ MAX9	A321/neo
Maximum Mass	88,541 kg	97,400 kg
Maximum Load on Main Gear	41,671 × 9,8 = =408,3758 kN	46,280x9,8= =453,544 kN
Main Gear Tire Pressure	1,59 MPa	1,57 MPa



AIRPLANE MODEL	UNITS	MAX DESIGN TAXI WEIGHT	V_{NG} STATIC AT MOST FWD C.G.	V_{NG} STATIC + BRAKING 10 FT/SEC² DECEL	V_{MG} PER STRUT AT MAX LOAD AT STATIC AFT C.G.	H PER STRUT STEADY BRAKING 10 FT/SEC² DECEL	H PER STRUT AT INSTANTANEOUS BRAKING (μ = 0.8)
737-7	LB	177,500	18,918	30,637	82,866	27,566	66,293
	KG	80,512	8,581	13,897	37,587	12,504	30,070
737-8 / -8-200 / BBJ MAX 8	LB	182,700	15,894	26,282	85,258	28,373	68,206
	KG	82,871	7,209	11,921	38,672	12,870	30,938
737-9 / BBJ MAX 9	LB	195,200	15,514	25,639	91,868	30,315	73,494
	KG	88,541	7,037	11,630	41,671	13,751	33,336
737-10	LB	198,400	13,613	23,251	93,679	30,812	74,944
	KG	89,992	6,175	10,546	42,492	13,976	33,994

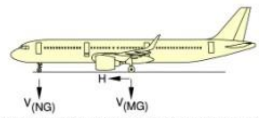
Fig. 5. Technical Characteristics of Aircraft B737-9/BBJ MAX9.

**ON A/C A321neo



A321 AIRCRAFT CHARACTERISTICS - AIRPORT AND MAINTENANCE PLANNING

C A321neo



$V_{(NG)}$ MAXIMUM VERTICAL NOSE GEAR GROUND LOAD AT FWD CG
$V_{(MG)}$ MAXIMUM VERTICAL MAIN GEAR GROUND LOAD AT AFT CG
H MAXIMUM HORIZONTAL GROUND LOAD FROM BRAKING

1	2	3		4	5		6	
		$V_{(NG)}$			$V_{(MG)}$ (PER STRUT)		H (PER STRUT)	
WEIGHT VARIANT	MAXIMUM RAMP WEIGHT	STATIC LOAD AT FWD CG		STATIC BRAKING AT 10 ft/s? DECELERATION	STATIC LOAD AT AFT CG		STEADY BRAKING AT 10 ft/s? DECELERATION	AT INSTANTANEOUS BRAKING COEFFICIENT = 0.8
A321NEO WV050 (CG 38.02%)	89 400 kg (197 100 lb)	8 680 kg (19 125 lb)	17.5 % MAC (a)	14 190 kg (31 275 lb)	42 700 kg (94 125 lb)	38.02 % MAC (a)	13 890 kg (30 625 lb)	34 160 kg (75 300 lb)
A321NEO WV050 (CG 37 %)	89 400 kg (197 100 lb)	8 680 kg (19 125 lb)	17.5 % MAC (a)	14 190 kg (31 275 lb)	42 580 kg (93 875 lb)	37 % MAC (a)	13 890 kg (30 625 lb)	34 070 kg (75 100 lb)
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A321NEO WV052	93 900 kg (207 025 lb)	8 640 kg (19 050 lb)	17.5 % MAC (b)	14 190 kg (31 275 lb)	44 720 kg (98 600 lb)	36.88 % MAC (a)	14 590 kg (32 175 lb)	35 770 kg (78 850 lb)
A321NEO WV053	93 900 kg (207 025 lb)	8 640 kg (19 050 lb)	17.5 % MAC (b)	14 110 kg (31 100 lb)	44 720 kg (98 600 lb)	36.88 % MAC (a)	14 590 kg (32 175 lb)	35 770 kg (78 850 lb)
A321NEO WV056 (CG 37.12 %)	92 900 kg (204 800 lb)	8 640 kg (19 050 lb)	17.5 % MAC (b)	14 110 kg (31 100 lb)	44 270 kg (97 600 lb)	37.12 % MAC (a)	14 440 kg (31 825 lb)	35 420 kg (78 100 lb)
A321NEO WV056 (CG 37 %)	92 900 kg (204 800 lb)	8 640 kg (19 050 lb)	17.5 % MAC (b)	14 110 kg (31 100 lb)	44 250 kg (97 550 lb)	37 % MAC (a)	14 440 kg (31 825 lb)	35 400 kg (78 050 lb)
A321NEO WV063 (CG 37.5 %)	91 400 kg (201 500 lb)	8 640 kg (19 050 lb)	17.5 % MAC (b)	14 110 kg (31 100 lb)	43 600 kg (96 125 lb)	37.5 % MAC (a)	14 200 kg (31 300 lb)	34 880 kg (76 900 lb)

NOTE:
(a) LOADS CALCULATED USING AIRCRAFT AT MRW.
(b) LOADS CALCULATED USING AIRCRAFT AT 89 000 kg (196 200 lb).

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Maximum Pavement Loads
(Sheet 1 of 2)
FIGURE-7-3-0-991-045-A01

Fig. 6. Technical Characteristics of Aircraft A321/neo.

Mid-year number of take offs for B737-9/BBJ MAX9 $N_1 = 5000$; for A321/neo $N_2 = 5000$. The calculation of the runway strength was also performed in accordance with US regulations [1, 2, 3].
The results of the calculations in the FAARFIELD program are shown in Fig. 7. The alternative variant of the structural integrity with a flexible airfield pavement is considered and calculated in solutions and offers: asphalt concrete A40 (brand I, type A) – 16 cm; asphalt concrete A40 (brand I, type A) – 16 cm; gravel processed by bitumen – 8 cm; gravel – 45 cm; sand – 22 cm; reinforcing mesh; gravel – 25 cm; reinforcing mesh;

compressed soil.
The results of the calculations of the alternative variant of the runway construction with a flexible pavement with the modulus of the subgrade elasticity E=24 MPa and E=28 are shown in Fig. 8. For the flexible airfield pavement, the aircraft classification number is PCN 70/F/D/W/T, which is more than the ACN of B737-9/BBJ MAX9 and A321/neo. This means that the flexible airfield pavement can take different take-off and landing operations without mass and intensity restrictions.

2.2 The results of calculating and designing the airfield pavements by the example of Mykolaiv International Airport

According to the survey, materials at the airport are: Rectangular shape runway: 2555x43,8 м; Airfield class – B (4C); Pavement – monolithic cement concrete reinforced by asphalt concrete; Runway has a planned area of 65 m wide on both sides from the artificial runway; Runway and apron are connected by taxiway-A 112 m length. The width of taxiway-A is 21 m.
Pavement – cement concrete reinforced by asphalt concrete.
With a total area of 65 500m2, the apron is designed to service aircrafts on AP1 – AP9. The AP7H is equipped with a heliport deck. Apron pavement is cement concrete partially (on AP 7H-9) reinforced by asphalt concrete. The absolute minimum temperature (in January) is -30 ℃. The absolute maximum temperature (in July) is +39 ℃.
Thus, the shoulders are located symmetrically on both sides of the runway so that the total width of the runway and its shoulders is 60 m for the airfield code letter D. The existing design of artificial runway surfaces, AP, and the apron of the Mykolaiv International airport is shown in fig. 9 *a, b*. For a long time of existence, airfield coverings have worked their calendar endurance. Operational inspection and monitoring of coatings are carried out regularly. As the project envisages the reconstruction of the artificial runways with a change in geometric dimensions, the air approaches are also changing. The runway is planned to be expanded from 43.8 to 45 m. On both sides of the runway edge, there are shoulders 7.5 m wide each. The calculation of the runway strength was also performed in accordance with U.S regulations [1, 2, 3].
Two brands of the upper (designed) layer of cement concrete pavement were considered: Btb4.8 / 60 and Btb4.4. The calculation was performed for 3 takeoffs per hour of the aircraft B767-300F and 3 take offs per hour of the aircraft A321-200. The results of the calculations are shown below in fig. 10.
For the thickness of the cement concrete upper layer with a thickness of 450 mm, it is necessary to make restrictions on the weight with the cement concrete class Btb4.4.
For the cement concrete class Btb4.8, the classification number of airfield pavement is PCN 51/R/A/W/T, for Btb4.4 - PCN 44/R/A/W/T with the thickness of upper layer pavement of 450 mm.

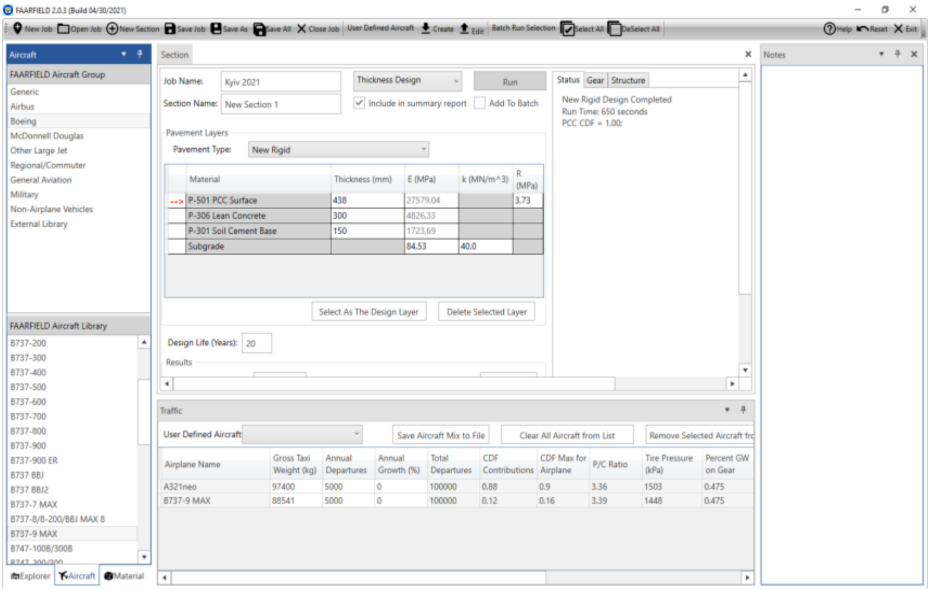

Fig. 7. The Results of the Calculations of the Rigid Cement-Concrete Runway Pavement of International Airport «Kyiv (Zhulyany)» (PCN 70/R/C/W/T WITH A COATING THICKNESS OF 44 CM).

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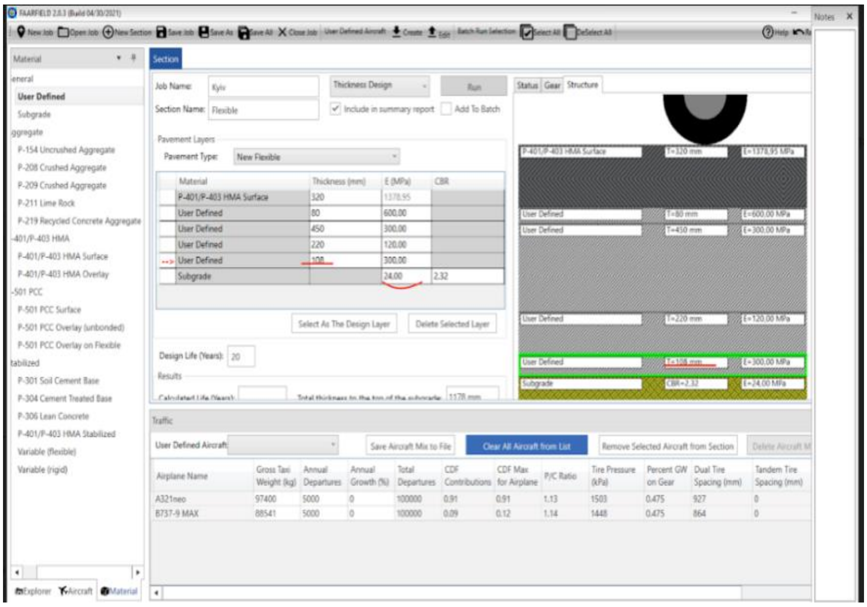

Fig. 8. The Results of the Calculations of the Alternative Variant of the Runway Construction with a Flexible Pavement with the Modulus of the Subgrade Elasticity E=24 MPa and E=28 MPa.

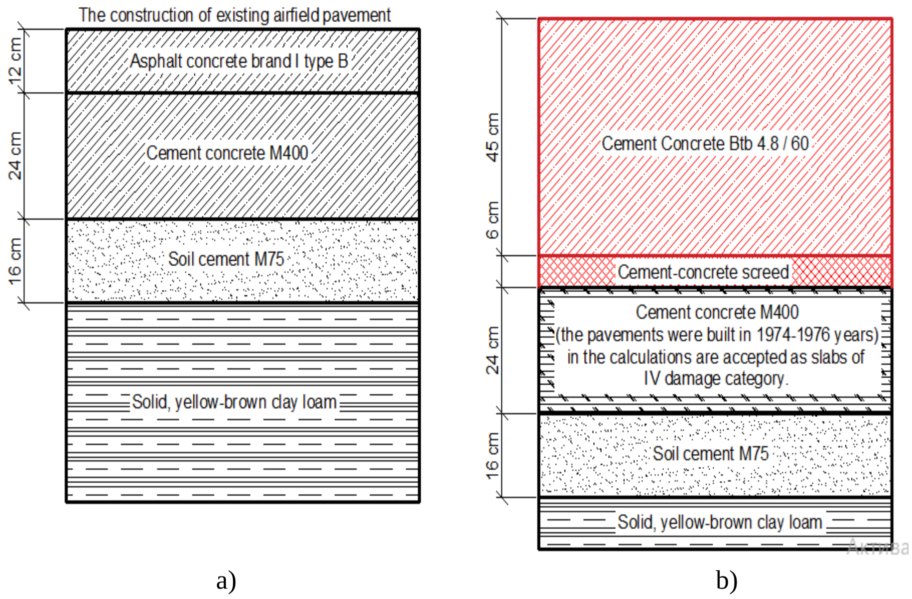

Fig. 9. Airfield Pavement Constructions of International Airport «Mykolaiv»: a) Existed Construction; b) Proposed Construction.

This is more than the value of the ACN, which allows accepting aircrafts B767-300F and A321-200 without restrictions on weight and intensity.

3. Discussion and interpretation of the results

Aircraft with an ACN number that is equal to or less than the PCN pavement of an airfield element may perform take-off and landing operations without restrictions, as shown by the calculations of rigid and non-rigid airfield pavements of International Airports «Mykolaiv» and «Kyiv». Given the probability of increasing the intensity of the load on the pavement and the number of take-off and landing operations by aircraft with ACN > PCN, it is possible that the airfield may need to operate in excess of bearing capacity.

According to the «International Standards and Recommended Practices» (ICAO, Doc 9157-AN/901 Chapter 2.), it is allowed (in certain circumstances) to fly by aircraft even with the maximum ACN. For example, from the practice of Canada, such take-off and landing operations are possible provided the readiness of the authorized body of the airport to make financial operations for pre-schedule repairs. Also, according to the practice of French, there is a minimum danger for an aircraft landing on the runway with insufficient bearing capacity. Even landing an excessively heavy aircraft (loads significantly exceed the bearing capacity of the runway) will undoubtedly cause some damage to the pavement, but without any damage to the aircraft itself, and the owner of the aircraft will in no way be liable for such damage. However, the load from the aircraft must not, in any case, exceed the permissible one (for this aircraft) for all pavements more than 50%, except for aprons, where such exceedances are limited to 20%.

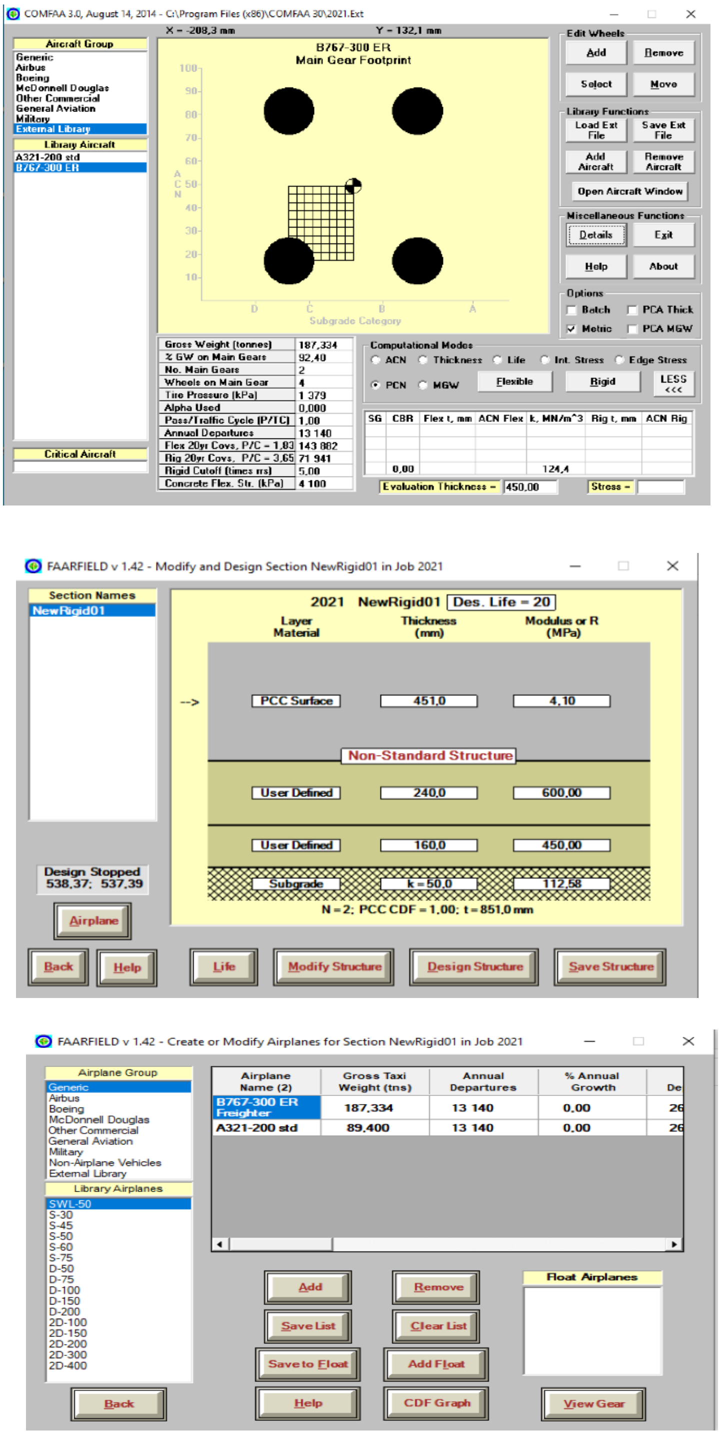

Fig. 10. The Results of Classification Numbers Calculation of PCN Airfield Pavement of the

In the future, after performing take-off and landing operations of the aircraft with overload, it is necessary to make additional inspections of the pavement with the fixation of any deterioration of their condition. In the case of new defects (through cracks, chips, and chips at the edges and corners of slabs, subsidence, etc.), which can lead to unacceptable pavement damage and pose a danger to flight safety, it is necessary to stop take-off and landing operations and perform necessary repairs.
Mykolaiv International Airport for the Cement Concrete Classes Btb4.4 and Btb4.8.
In case of a significant load increase on pavement and numbers of take-off and landing operations by aircraft, formation of new destructions or significant development of existing ones, overhaul or reconstruction, it is necessary to inspect and evaluate the technical condition of artificial airfield pavements, analyze flight intensity, aircraft types and perform a new calculation of PCNs.

Conclusion

To solve the problem of evaluating the transport and operational condition of aerodrome pavements of International Airports «Mykolaiv» and «Kyiv», the article provides theoretical research, which included the development of calculation schemes and models of airfield pavements based on world experience in design and calculation. In the FAARFIELD program was performed computer modeling and calculation of PCNs of rigid pavements of International Airports «Mykolaiv» and «Kyiv» and non-rigid airfield pavement of International Airport «Kyiv». According to the results of calculations, the PCNs of the airfield pavements are higher than the classification numbers of the ACN aircraft.
The calculation of rigid and non-rigid airfield pavement of International Airport «Kyiv» was performed under the action of loads from aircraft B737-9/BBJ MAX9 and A321/neo. For the rigid airfield pavement, the classification number is PCN 70/R/C/W/T, for the non-rigid one is PCN 70/F/D/W/T, which is more than ACN of B737-9/BBJ MAX9 and A321/neo aircrafts. This means that the rigid and non-rigid airfield pavement can take different take-off and landing operations without mass and intensity restrictions.
The calculation of the rigid airfield pavement of International Airport «Mykolaiv» was performed for the action of the load from the cargo aircraft B767-300F and the passenger aircraft A321/neo. For the thickness of the cement concrete upper layer with a thickness of 450 mm, it is necessary to make restrictions on the weight with the cement concrete class Btb4.4.
For the cement concrete class Btb4.8, the classification number of airfield pavement is PCN 51/R/A/W/T, for Btb4.4 - PCN 44/R/A/W/T with the thickness of upper layer pavement of 450 mm. This is more than the value of the ACN, which allows accepting aircrafts B767-300F and A321-200 without restrictions on weight and intensity. For the thickness of the cement concrete upper layer with a thickness of 450 mm, it is necessary to make restrictions on the weight with the cement concrete class Btb4.4.

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