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HELIPORT PAVEMENT DESIGNING FEATURES

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Absract. In recent years, there has been a significant progress in helicopter traffic, its volume increasing every year. To solve the transport problem of megacities, first of all heliports should be built in the largest cities, with the corporate sector as the customers, and the possibility of excursion transport flights not excluded. UTair-Ukraine (the world's largest airline in terms of helicopter fleet operating more than 300 helicopters of various models) plans to actively develop the helicopter business in Ukraine.

To date, only one modern helipad has been built in the capital of Ukraine – Dnipro-1. Kyiv needs at least 19 helicopter pads located in such a way as to reduce the traffic load on roads and provide an opportunity to evacuate the population in case of an emergency.

The article considers the history of the development of designing hard surface airfields and heliports design, the main heliport parts, determination of the helipad geometric parameters, helicopters classification by their impact on the covering.

Key words: helicopter, designing airfields and heliports coverings, helipad, calculation of aerodrome pavements.

INTRODUCTION

The modern state advancement is impossible without the development and continuous improvement of the transport system. The priority in this matter is given to air transport. During the Soviet era, passenger air transportation between settlements was generally available. In the early 50's, they began to use different types of helicopters (Mi-1, Mi-2, Mi-4, Ka-15, Ka-18) to transport a variety of goods and passengers in hard-to-reach places. Later on Mi-6, Mi-8, Mi-10, Ka-26 helicopters were put into operation in the agriculture area.

With the onset of economic growth, helicopter traffic has occupied a special place in commercial aviation. Maneuvrability, small landing area and the ability to do without the airfield in case of necessity allow helicopters to solve problems not inaccessible to other modes of air transport.

At present, helicopter transportation is an integral part of business aviation throughout the world, especially in megacities. Thus, according to the Kyiv Aeronautics Association statistic data, only a few hundreds of helicopters are currently in operation in Ukraine. At the same time, the total number of private and corporate helicopters in the EU is estimated in tens of thousands. Accordingly, the infrastructure is being developed. For example, in New York there are about 300 helipads built. While in Ukraine, like other former USSR countries, this sector of transportation is still underdeveloped, the main reason being the ban on flights over cities, lack of sufficient number of heliports, lack of modern regulations that would take into account the design features of modern helicopters types and insufficient number of the required aircraft type.

MATERIALS AND METHODS

The history of designing aerodrome and heliport pavements. There is one consistent pattern in the beginning of mass helicopter usage – its designing follows aircraft designing. The relative simplicity of the aircraft design puts the latter, in relation to the helicopter, in the position of experimental samples for accumulating theoretical, practical and organizational designing experience. The same applies to designing heliports (master plan, composition of buildings and structures, etc.) and calculation of pavemnents for helicopters. Mass use of helicopters in the world falls onto the second half of the twentieth century and at this stage of development they were based at civil and military airfields. That is, there was no need to separate the method of designing heliport pavement from the airfield one. The first cement-concrete pavements at airfields were built in the 20's – 30's of the last century, when no calculation of the pavements strength was performed, and their thickness was determined based on the common sense. Heliport covering was not calculated for strength either [1].

Until early 1950's, improvements in coverings followed the way of gradually increasing their thickness. The next rapid development in the theory of covering calculation was primarily due to the emergence of heavy aircraft on air routes. There was no separate method of calculating coverings for helicopter loads, as this type of air transport was not sufficiently developed yet at that time. At that stage, the theoretical basis for calculating pavements (single- and double-layer type) for the impact of operating loads was developed [ibid]. In addition, considerable attention was paid to the full-scale survey of paving slabs, i.e., the issue of calculating the aerodrome pavements began to be considered comprehensively, taking into account all the factors (both operational and climatic) affecting the pavement during its service life. Since 1960s, the use of aerodrome smooth prefabricated slabs (ASS) for pavement construction of both airfields and heliports started growing.

As a result of these studies, a single theory of aerodrome pavement calculation was developed [ibid]. Its main provisions can be formulated as follows:

– pavement is calculated for the impact of static load;

– as a mathematical model of the pavement Kirchhoff-Winkler elastic basis plate, corresponding to the Winkler hypothesis is adopted [2];

– taking into account seasonal changes in soil resistance during the year, the soil base calculated characteristics are taken relative to the period of the lowest pavement strength (spring melting), i.e., the bed ratio value is taken as the lowest possible for each soil type in specific engineering and geological conditions;

– the plate is considered to be infinite in plan, and the edge loading is taken into account by means of the transition coefficient (depending on the covering design) and is taken according to [3], but it is desirable (especially for two-layer coverings) to determine it on the basis of field studies.

$$K = \frac{E_b \cdot t^3 \cdot \rho}{12 \cdot (1-\mu_b) \cdot \left[f(d) + \sum_{i=2}^{n} \overline{m}_{x(y)i} \right] \cdot F_d}, \qquad (1)$$

where E_b – modulus of concrete elasticity;
t – the covering plate thickness;
ρ – the deformed surface curvature under the action of force F_d;
μ_b – Poisson's ratio of concrete;
$f(d)$ – function, the value of which is taken by a separate formula;
$\overline{m}_{x(y)i}$ – unit moments in the loaded plate are determined according to [3];

– for reinforced concrete coverings, the internal forces redistribution is taken into account;

– when calculating multilayer coverings, provision is made for joint operation of the covering layers;

– temperature stresses occurring in the pavement slabs under the influence of temperature – humidity fluctuations, as well as the increase in concrete strength over time are taken into account by introducing appropriate hard pavement condition coefficients into calculation.

Helipads, parking lots and taxiways coverage is made only in one layer, usually of ASS [4]. Therefore, it is of great importants for the plates tensely deformed state to connect them with each other. Numerous theoretical

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calculations, experimental surveys, as well as the practice of aerodrome pavements operation have proved that seams in the pavement cause a significant reduction in the bearing capacity of the pavement edge and corner sections as compared to its central area.

Nowadays, various types of butt joints are used in practice. And the ability of butt joints to transfer load through the joint from plate to plate is determined both theoretically and experimentally. In this case, the Sutherland-Teller formula [1] is often used to assess the quality of seam transmission, which can be used to calculate the plates, given the butt joints flexibility.

$$W = \frac{2 \cdot w_c}{w_c + w_H}, \quad (2)$$

where w_c – deflection of the adjacent plate face;
W – load transfer efficiency;
w_H – deflection of the stressed plate face.

Figure 1 shows, as an example, a graph of the transition factor dependence on the rigidity of the elastic bonds in the covering seams. The calculation was performed for the following data: 7 x 7 m slabs, thickness – 240 mm, concrete elasticity modulus – 3,3 x 10^4 MPa, Poisson's ratio – 0,15, the elastic base bed coefficient – 63 MN/m^3.

As can be seen from Figure 1, without connection between the covering plates, the bending moment at the edge load is 84% more than that under the central load. Provided the plates are connected with an ideal hinge, the extreme moment exceeds the central moment by only 13%.

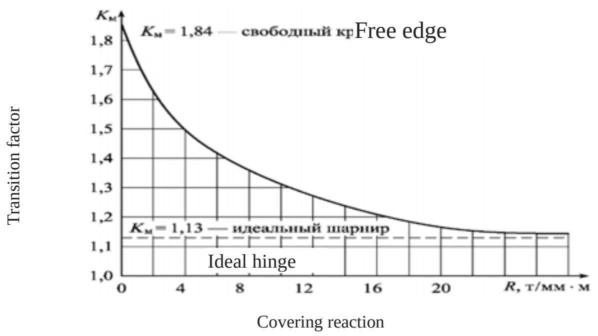

Fig. 1. Butt joint rigidity impact on the pavement bearing capacity

In the calculation it is also desirable to use a real landing gear scheme of the helicopter design (taking into account the number of gears, number of wheels, tire pressure, distance between the main gears, the distribution of the helicopter take-off weight between the gears). The helicopter landing gear has much incommon with the aircraft landing gear. It performs the same functions (provides helicopter parking on the ground, its movement during take-off, taxiing and transportation). There are 4 main types of helicopter landing gear (Fig. 2), and combinations of landing gear types shown below are not excluded [4].

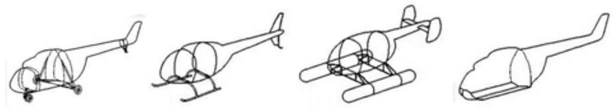

Fig. 2. The main types of helicopter landing gear:
1 – wheeled landing gear; 2 – slides;
3 – float type; 4 – "boat" type

The main sections of the heliport. Determination of the helipad geometric parameters. *Heliport (helicopter station)* is land (water) or a specially prepared area (for example, on a building roof), having a set of structures and equipment to provide helicopter take-off and landing (with or without the use of airbags), taxiing, storage and maintenance. A helipad is a specially prepared area for regular or irregular helicopter take-offs and landings. According to the current regulations, the covering is calculated without taking into account the airbag. The helipad includes an operation area, providing helicopter parking, lift-off and landing, and safety strips located around the perimeter of the operation area [5–7].

The heliport usually includes the following buildings and structures: a passenger terminal with an apron, when the helipad is more than 100m away from the airport, or any other structure to protect passengers from precipitation and air flow, created by the helicopter rotors; take-off strip or a runway with open approaches to it; helicopter parking lots; taxiways; a pedestrian alley connecting the passenger terminal with the airport terminal; mooring platform (only in case helicopters are not based at this airport). The main parts of the heliport are shown in Fig. 3.

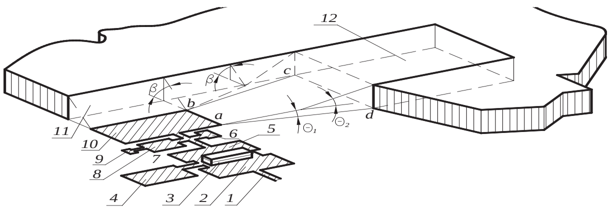

Fig. 3. The main parts of the heliport:
1 – access road; 2 – station area; 3 – passenger terminal;
4 – servicing and maintenance area; 5 – apron;
6 – individual helicopter parking lot; 7 – taxiways;
8 – group parking lots; 9 – mooring platform; 10 – ground take-off strip or runway; 11 – side obstacle restriction area; 12 – air approach obstacles restriction area

Figure 4 shows the helipad main parts.

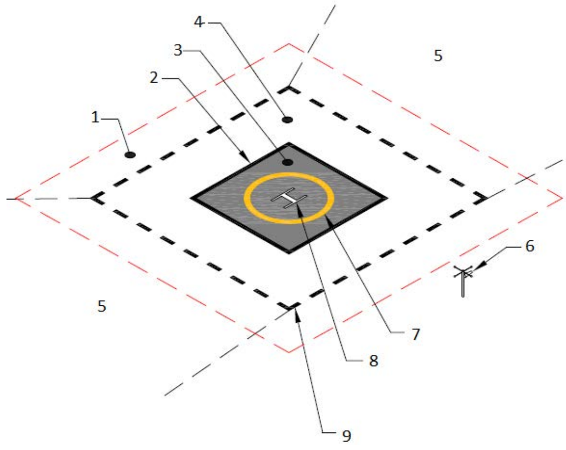

Fig. 4. The main parts of the landing site [7]: 1 – Safety area; 2 – Touchdown and lift-off area (TLOF) perimeter marking; 3 – TLOF; 4 – Final approach and take-off area (FATO); 5 – Approach/Departure surface; 6 – Wind cone – an indicator of wind direction in the form of a cone; 7 – Touchdown / Positioning Circle (TDPC) marking (for restriction of the helicopter landing zone); 8 – Heliport identification marking (for the landing site); 9 – In-Ground FATO edge marking (for the perimeter of the approach and take-off area)

According to the ICAO requirements, the marking should be done in green, but it is possibile to use yellow for marking as well [8].

Modern heliports are divided into basic and operational. Basic heliports consist of the following main elements: runway (landing site), taxiway system, helicopter parking lots, helicopter maintenance complex. A large number of helicopters (up to 100–150) are located at the basic heliports. This leads to large land areas under the heliport as a whole and helipad artificial coverings (take-off and landing sites, parking lots, taxiways, aprons).

Operational heliports include, as a rule, a paved runway, taxiways and one or several helicopter parking lots [5].

The taxiway (TW) width and the parking lot size in the plan form are affected only by the geometric parameters and taxiing characteristics of different helicopter types (landing gear track, deviation of the helicopter from TW axis when moving along it). Therefore these dimensions can be clearly determined for any helicopter type. But the problem of determining the optimal size of the landing site artificial covering remains open. There is no scientific approach taking into account all the factors affecting the size of the landing plan. The sizes of the sections are determined based on the helicopters dimensions (total length of the helicopter, the rotor diameter) and the qualification of the flight staff.

When taking off and landing, the type of helicopter take-off operation (with the use of the so-called "air cushion" or without it) is of great importance. When using an air cushion, the helicopter gains horizontal speed within the action of the air cushion (i.e., at the altitude of 1,5–2 m). In case of "helicopter type" take-off, the helicopter reaches an altitude exceeding the height of the obstacles by 10 m, and only then gains speed [9].

In the case of landing using the "air cushion" effect, the helicopter descends to the hovering altitude and hovers over the helipad or above the airfield area, then moves to the center of the pad and descends vertically to its surface.During landing, deviations of the axis from the landing site center are possible (Fig. 5). Analyzing these factors, it can be stated that some of them, affecting the size of the site, depend on the design features and defined for each helicopter type, namely: the characteristics of the helicopter landing gear, the minimum distance from the pavement edge to the landing gear wheels.

The main factor affecting the pavement size of the landing sites is the deviation of the helicopter rotor axis from the site axis at the moment of the helicopter touchdown, i.e., its wheels contact with the pavement. As it can be seen from the scheme (Fig. 1.5), this factor is connected with a number of values, whose effect on the deviation is rather probable and depends on some random factors [7].

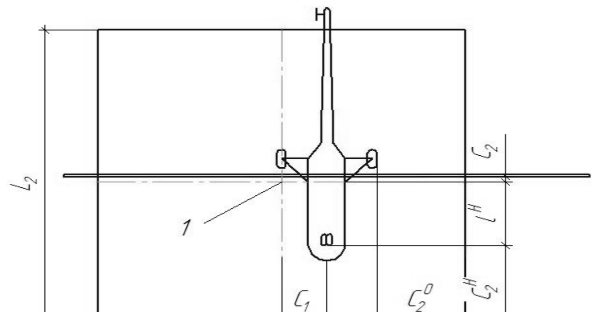

Fig. 5. Scheme for determining the size of helicopterlanding sites: 1 – the center of the landing area; 2 – the pavement borders

Currently, the landing gear wheels deviation from the pavement borders is unspecified, as well as the amount of the helicopter deviation at the moment of touchdown. The minimum size of the landing site can be calculated by the following dependencies [10]:

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$$L_1 = B_к + 2(C_1 + C_2)\,, \qquad (3)$$

$$L_2 = 2(l_н + C_1 + C_2)\,, \qquad (4)$$

where L_1 – the size of the landing site side at the maximum approximation of the helicopter main gear wheels to the pavement edge;

$B_к$ – the helicopter landing gear track by external tires;

C_1 – deviation of the helicopter rotor axis from the center of the site;

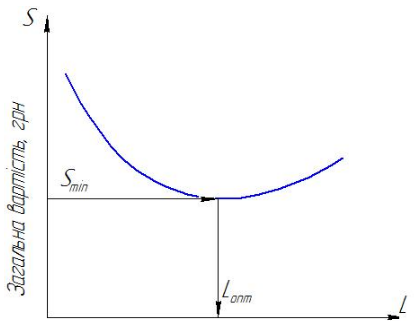
C_2 – the minimum allowable distance from the pavement edge to the helicopter wheels;

L_2 – the size of the site at the maximum approach of the helicopter nose wheel to the pavement edge;

$l_н$ – helicopter landing gear base.

The time spent by the helicopter pilot for landing operations depends on the size of the pavement. For example, smaller platforms require more time to manoeuvre to perform a more accurate landing, and, accordingly, flight costs, true and inverse dependence are increased. It should be noted that the cost of modern helicopters flight time is rather high and it depends on the specific helicopter type. Thus, for the Agusta AW139 helicopter performing air transportation (excluding fuel costs) the flight hour cost is about UAH 10 800, for the Agusta A109C helicopter – UAH 6 400.

Since the increase in the landing site size raises the cost of construction and operation, the optimal size of the site can be calculated using the Szag = f (L) function. In general, the graph will look like this (Fig. 6).



The size of the site

Fig. 6. Dependence of the total cost of construction on the size of the site

Summarizing the above, it should be noted that in determining the heliports plan parameters, not only the performance characteristics must be taken into account, but the cost, being of great importance for modern transport, as well. In particular, the helipad size should have a minimum cost, while not increasing the time for maneuvering.

Classification of helicopters by their impact on the surface. As for the calculation of covering for the helicopter loads impact, according to SNiP 2.05.08-85, calculating the heliport pavements strength should be performed in the same fashion as for group A areas (Fig. 7). That is, the heliport covering is calculated as the main taxiways pavement.

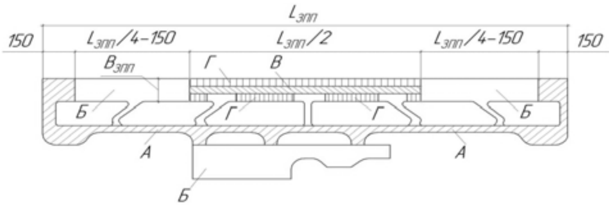


Fig. 7. The scheme of airfield pavement division into groups of sections:
А – main taxiways; Б – runway sections adjacent to its end sections; В – the middle part of the runway; Г – edge (by width) sections in the middle part of the runway, except for those adjacent to the connecting taxiways

When calculating the pavement strength, the coefficients of dynamism and unloading are taken according to table 1 [3].

Table 1

Values of dynamics and unloading coefficients fordifferent groups of sections

Ggroup of airfield pavement sections	Unloading ratio, γ_f	The dynamics coefficient Kd at the internal air pressure in the tires, MPa (kgs/cm²)		
		1 (10) and less	from 1,0 (10) to 1,5 (15)	over 1,5 (15)
А	1	1,2 (12)	1,25 (12,5)	1,3 (13)
Б	1	1,1 (11)	1,15 (11,5)	1,2 (12)
В and Г	0,85	1,1 (11)	1,1 (11)	1,1 (11)

Structures (trusses, beams, spans, etc.) of helicopter take-off – landing sites, located on drilling platforms, buildings and other structures, should be calculated for the concentrated load of the helicopter maximum take-off weight with an overload factor of 1,5.

Heliports pavements are calculated by the method of boundary conditions for the impact of aircraft vertical loads as structures lying on an elastic base. When calculating according to [3], the following load classification is used (Table 2).

Moreover, it is taken into account that the main support is a single-wheel gear, as well as the fact that the load from heavy helicopters (take-off weight over 17 tons) is equal to category III of standard load (table 3), medium (take-off weight from 5 to 15 tons) – to category V and light (less than 6 t) – to category VI.

Table 2

Classification of helicopter loads according to SNiP 2.05.08-85

Helicopter category by take-off mass	Regulatory load Fn on the main (conditional) support, кН (tf)	Internal air pressure in wheel tires, MPa (kgs/cm²)
Heavy	170 (17)	0,7 (7)
Medium	60 (6)	0,6 (6)
Light	20 (2)	0,4 (4)

Table 3

Classification of regulatory loads according to SNiP 2.05.08-85

Regulatory load category for airfields	Regulatory load Fn on the main (conditional) support MPa, (kg / cm²)	Internal air pressure in wheel tires, MPa (kgf / cm²)	Basic support
Higher category I II III IV	850 (85) 700 (70) 550 (55) 400 (40) 300 (30)	1,0 (10)	Four-wheel
V VI	80 (8) 50 (5)	0,6 (6) 0,4 (4)	Single-wheel

The classification of helicopters abroad differs significantly from that proposed during the Soviet era. For example, according to the ICAO classification airplanes and helicopters are divided into 4 separate classes depending on the take-off weight (Table 4). In some cases, given the unique flight characteristics, it is allowed to assign an aircraft a higher class.

Table 4

ICAO classification of airplanes and helicopters by the take-off weight

Aircraft class	Airplanes	Helicopters
1	75 t and more	10 t and more
2	30–75 t	5–10 t
3	10–30 t	2–5 t
4	up to 10 t	up to 2 t

The International Aeronautics Federation (FAI) has developed and implemented its own, more detailed aircraft classification by take-off weight. According to this classification, all helicopters are classified as class E-1, and for more accurate consideration of design features additional subclasses are introduced, so the classification of helicopters according to FAI looks like this (Table 5).

Table 5

FAI classification of helicopters depending on take-off weight

Helicopter class	Helicopter take-off weight
1	2
1	2
E-1a	up to 0,5 t
E-1b	0,5 t – 1 t
E-1c	1 t – 1,75 t
E-1d	1,75 t – 3 t
E-1e	3 t – 4,5 t
E-1f	4,5 t – 6 t
E-1g	6 t – 10 t
E-1h	10 t – 20 t
E-1j	30 t – 40 t

Table 6

Technical characteristics of modern helicopters (by load classes)

Aircraft type	Maximum take-off weight, t	Type of main gear	Pressure in the main gear wheel tires, MPa	Main gear load, кN	Load on one wheel, кN	Year of commissioning
B-12	105	Two-wheel	0,8	420,00	210,00	–
Mi-26	56,00	Two-wheel	0,6	224,00	112,00	1978
Mi-38	15,60	Single-wheel	0,55	63,96	63,96	–
Mi-8	13,00	Single-wheel	0,5	52,00	52,00	1964
Ka-27	12,00	Single-wheel	0,5	46,80	46,80	1981
Mi-24	11,50	Single-wheel	0,45	47,15	47,15	1971
Ka-29	11,50	Single-wheel	0,55	46,58	46,58	1987
Ka-32	11,00	Single-wheel	1,1	44,00	44,00	1986
Ka-62	6,50	Single-wheel	0,50	26,00	26,00	-
Mi-2	3,55	Single-wheel	0,40	13,20	13,20	1966
BellQuadTiltRotor	45,0	Two-wheel	0,7	180,00	90,00	-
Bell V-22 Osprey	27,44	Two-wheel	0,6	110,00	55,00	2005
AW101	15,60	Two-wheel	0,6	64,00	64,00	2000
1	2	3	4	5	6	7
EC225	11,00	Single-wheel	0,6	44,00	44,00	2000
Agusta AW139	6,40	Single-wheel	0,5	25,60	25,60	2003
EC155 B1	4,95	Sliding gear				2002
EC145	3,59	Sliding gear				1999
Bell 429	3,18	Sliding gear				2007
Agusta AW 109 Power	2,85	Sliding gear				1997
EC120 B	1,72	Sliding gear				1997
R66 Turbine	1,23	Sliding gear				2010

Parameters of the most common helicopters of domestic production in the countries of the former USSR are shown in Table 6. Given the fact that the helicopter transportation sector in our country is just beginning its revival, Table 6 shows the characteristics of most helicopters used in Ukraine, as well as thouse of foreign helicopters of such manufacturers as: Eurocopter, Bell, Robinson, Agusta. The table also gives the characteristics of the Bell Boeing Quad Tilt Rotor – one of the largest aircraft in the world, although its serial production has not been established yet and the B-12 helicopter designed in Soviet times, which is not mass-produced.

Based on the above helicopter types, a diagram of their distribution by loading classes is constructed according to the ICAO classification (Fig. 8).

At present, there are large differences in the classification of helicopters by take-off weight. Thus, according to [6; 7], only three weight categories are distinguished, the maximum weight that falls on the main gear is normalized. Some of the existing superheavy helicopters go beyond the classification proposed by the current regulations (for example, Mi-26 [4]). Foreign classification systems divide helicopters into 4 weight categories (ICAO) and 9 categories (FAI), the main classification feature being the full take-off weight of the helicopter, and not the load on the main gear. Due to the existing differences in the helicopter classification systems, the task of determining the helicopter impact on the pavement is rather complicated. Therefore, there is a need to develop and substantiate a modern classification system that would take into account the peculiarities of helicopter engineering.

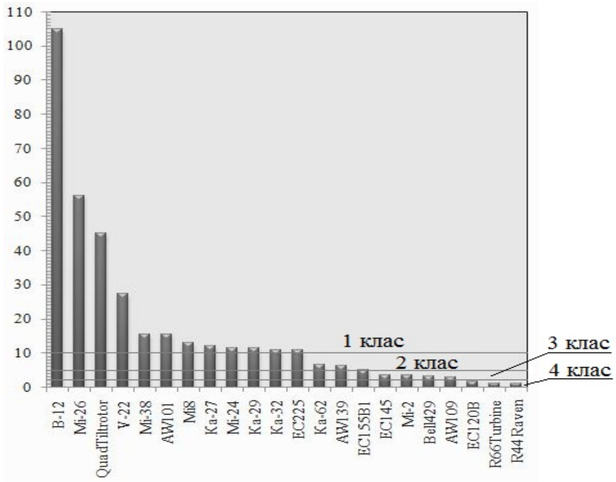


Fig. 8. Helicopters classification by take-off weight according to the ICAO

CONCLUSION

1. Helicopter issues are becoming increasingly important. Industry experts estimate the market volume of the former Soviet Union in the coming years at about 12 000 helicopters. And only 7% of this volume will fall on heavy helicopters, the rest – on medium – weight and light ones. At the same time, the regulatory literature, both foreign (ICAO, FAA recommendations) and domestic (SNiP 2.05.08-85) does not focus on the construction of helipads for light and medium-weight helicopter categories.

Taken into account the prevalence of helicopters in urban areas, in New York, for example, there are more than 300 helipads, in San Paulo – more than 200, while at the same time in Kiev it is only planned to create a network of helipads, the need to increase the scientific and technical level of helipads designing is urgent.

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