Piotr Nita
Prof. dr hab. inż.
Instytut Techniczny Wojsk Lotniczych w Warszawie
piotr.nita@itwl.pl

Małgorzata Linek
Dr inż.
Wydział Budownictwa i Architektury
Politechnika Świętokrzyska w Kielcach
linekm@tu.kielce.pl

DOI: 10.35117/A_ENG_22_10_01

Influence of the media used in the operation of aircraft on the durability of airport cement surfaces

Abstract: The intensification of air operations in recent years has resulted in an increase in stresses and deformations in concrete pavements. In terms of mass, dynamic and temperature interactions, these are measurable phenomena that can be determined and predicted using appropriate methods and algorithms. Another type of impact that does not occur in an avalanche-like manner on pavements is their random destruction caused by the presence and operation of exploitation media. The article presents the impact of selected measures on the change of concrete parameters and its durability in the pavement structure. The effects of this impact are significant and clearly destructive for concrete pavements. In addition to the measurable decrease in the mechanical parameters of concrete, there is an interference of media with the concrete structure, which in the presence of extreme temperatures (positive and negative) is a challenge for concrete technologists, contractors and users of airport pavements. The nature of the impact of exploitation media is varied and in most cases there is a combined effect of them on pavements. It has been shown that the operational coatings currently applied to pavements are only partially effective for these media, and learning about the nature and manner of impact makes it possible to effectively limit these unfavorable, objectively occurring phenomena.

Keywords: Concrete airport pavement; Operating media

Introduction

The durability of airport structures, identified with the possibility of safe operation of aircraft on the surface, is a criterion of serviceability as a function of the assumed service life. Fulfillment of the standard requirements [15, 16], which specify in detail the parameters of concrete mix components and hardened concrete, guarantees the production of a composite with the desired mechanical, physical, and operational properties. So far, the assessment of the operational characteristics of concrete pavements at airports has been limited to obtaining satisfactory performance parameters, strength, and high resistance to low temperatures. The current operational procedures do not take into account in their assessment the effects of other technical media (except de-icing agents) from the operation of aircraft and the related random presence of these media on the concrete surface of the airport. Fuel spills during filling aircraft tanks or spillage of operating fluids from hydraulic, oil, and air systems are just some of the situations where operating media may come into direct contact with the surface concrete. The sources of such pollution may also be technical vehicles and other aircraft maintenance equipment. In the phase of pavement use, the presence of operating media takes place on selected fragments of the pavement. Such areas include, in particular, the ground service zones for the aircraft and any technical equipment that accompany the process of preparing the aircraft for flight and activities after touchdown. Areas, where the destructive effect of such measures is most often observed, are, in particular, aircraft parking areas, aprons in front of hangars, maneuvering routes, and end sections of runways. Such interactions are co-existing activities that complement the range of basic pavement loads (static, dynamic, natural, and forced thermal). The increase in the intensity of air traffic and the increasing weight of aircraft, as well as a significant number of observed surface damages on structures contaminated with operating media, make it necessary to assess the impact of these media on the durability of concrete airfield pavements. The need to take this issue into account in the context of assessing the durability of concrete pavements was noticed, among others, in works [6, 8, 9, 10, 11, 12, 13, 14, 18, 20]. The authors of papers [1, 7] draw attention to the negative impact of crude oil used in the concrete conditioning process, manifested by the occurrence of sulfate corrosion, an increase in the number of ettringite crystals in the cement matrix and the propagation of cracks. On the other hand, the aggressive impact of sulfuric acid contained in crude oil is indicated by the author [17]. This effect is manifested by the reduction or complete removal of calcium hydroxide $Ca(OH)_2$ in the hardened cement paste. The negative effect of oil on concrete parameters was shown in [2], and the mixtures of linseed oil with a white spirit were shown in [3, 4]. The author of the work [19] proved in his research that the increase in water absorption of concrete made with quartzite aggregate contributes to the reduction of its compressive strength to 11%. Conclusions formulated in terms of the impact of the increase in concrete water absorption on the reduction of its strength were also presented in the work [5] and concerned the reduction of the average strength by about 17%.

Airport cement concrete and operating media

The criteria for selecting the composition of the concrete mix were met in accordance with the requirements of the standard [15] by entering the mix curve in the range of good graining. Environmental impacts for corrosion due to carbonation (XF4), non-seawater chlorides (XD3), freeze-thaw (XF4), and abrasion (XM1) were assumed. The quantitative share of individual components included cement, coarse and fine aggregate, water and air-entraining, and plasticizing admixture (Table **1**). At the research stage, coarse aggregate from igneous rocks was used in the form of granite and basalt grits, whose grain sizes ranged from 2mm to 16mm. Low-alkaline cement with a class of 42.5 was used, assuming a W/C ratio of 0.4 and concrete class C30/37.

Tab.1. Percentage of components of concrete mixes with granite (MG) and basalt (MB) aggregate)

Mix designation	**MG**		**MB**	
CEM I cement 42.5 MSR/NA [%]	13,7		13,5	
Fine aggregate, fraction 0-2mm [%]	21,8		21,9	
Coarse aggregate, fraction 2-8mm [%]	34,6	58,8	31,5	59,0
Coarse aggregate, fraction 8-16mm [%]	24,2		27,5	
Water [%]	5,4		5,4	
Air-entraining admixture [%]	0,2		0,1	
Plasticizing admixture [%]	0,1		0,1	

Hardened concretes were used to assess the impact of operating media on the change of selected concrete parameters. The research procedure included a period of standard care (28 days in water at 20°C) and the impact of selected operating media. From the group of media used in aircraft and technical vehicles operated on airport pavements in Poland, two basic groups were selected: I—lubricants, and II - hydraulic fluids. Within each group, three different agents were analyzed, for lubricants: A - Nycolube 30, B - Nycolube 7870, and C - TurboNycoil 210A, and for hydraulic fluids: A - AeroShell Lubricating Oil 555, B - AeroShell Fluid 41 and C - AeroShell Master Finish RL 456.

The assessment included an analysis of the impact of the tested factors (presence or absence of media and curing time) on the change of selected concrete parameters (i.e. bulk density, water absorption, compressive strength, bending strength, and resistance to surface spalling) after various testing periods (marking indexes were adopted : k - control series stored in laboratory conditions - air-dry and 28, 56, 140 - respectively 28, 56 and 140 days of reaction of selected media to test series) - table **2**.

Tab. 2. Summary of the analyzed concrete parameters.

Tested concrete parameter	Standard guidelines	Response time	Lubricants			Hydraulic fluids		
			I-A	I-B	I-C	II-A	II-B	II-C
Bulk density	PN-EN 12390-7:2011	28, 56, 140	+	+	+	+	+	+
Impregnability		28, 56, 140	+	+	+	+	+	+
Compressive strength	PN-EN 12390-3:2011	28, 56, 140	+	+	+	+	+	+
Tensile strength while splitting	PN-EN 12390-6:2011	28, 56, 140	+	+	+	+	+	+
Resistance to surface flaking	NO-17-A204:2015	56 cycles	+	+	+	+	+	+

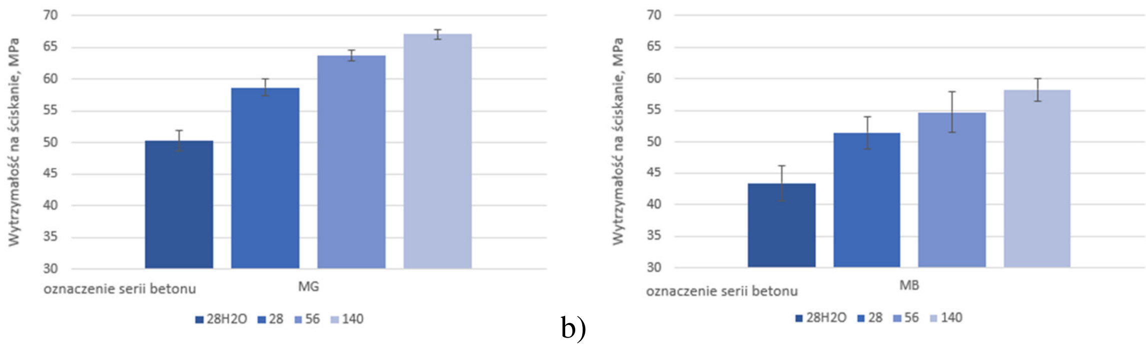
The characteristics of the consumables selected for analysis are listed in Table **3**.

Tab. 3. Basic parameters of consumables

Selected parameters	Lubricants			Ciecze hydrauliczne		
	I-A	I-B	I-C	II-A	II-B	II-C
Acid number	0,03 [mg KOH/g]	0,05 [mg KOH/g]	0,07 [mg KOH/g]	0,1[mg KOH/g]	0,2 [mg KOH/g]	0,1[mg KOH/g]
Kinematic viscosity at temperature +40 ^{o}C	> 11 [mm^2/s]	> 9 [mm^2/s]	> 15,8 [mm^2/s]	> 26 [mm^2/s]	> 13 [mm^2/s]	> 19 [mm^2/s]
Pour point	< -63 ^{o}C	< -57 ^{o}C	< - 60 ^{o}C	< -54 ^{o}C	< -60 ^{o}C	< -57 ^{o}C
Flash-point	> 135 ^{o}C	> 130 ^{o}C	> 190 ^{o}C	> 246 ^{o}C	> 82 ^{o}C	> 165 ^{o}C

Results and their analysis

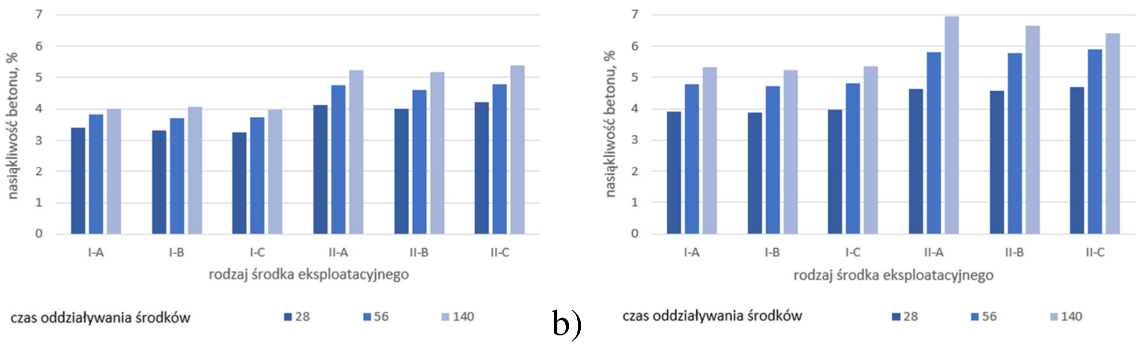
Based on the analysis of the obtained results (Fig. **1**), it was found that the designed classes of concrete C30/37 were met for both concrete series after a 28-day curing period. A higher level of average compressive strength was recorded for concrete made with granite aggregate, which is related to the parameters of coarse aggregate and the construction of the internal structure of the composite.



a) b)

1. Change in the average compressive strength of concrete series MG (a) and MB (b) as a function of curing time

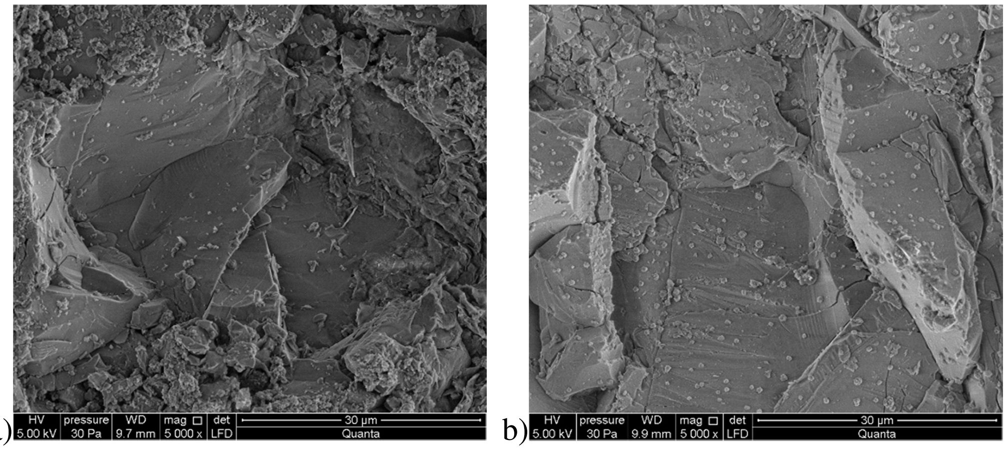
The assessment of the impact of selected media on the change of concrete parameters showed that for all the analyzed parameters, more favorable results were obtained for concrete based on granite aggregate.



a) b)

2. Influence of operating media on the change in the average water absorption of cement concretes as a function of time

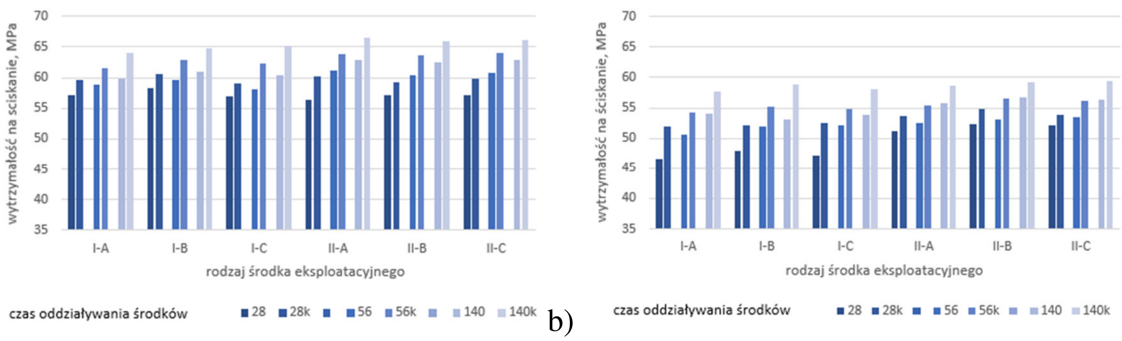
The assessed concretes significantly differ in the level of average water absorption (Fig. **2**). In each case, the medium used increases the average water absorption of concrete. This phenomenon, due to the possibility of affecting the frost resistance of concrete and the increased susceptibility of such concrete to the aggressive impact of external factors, is particularly undesirable. Maximum differences of 0.9% were obtained between concrete with granite aggregate and concrete with basalt aggregate. The results of concrete absorption are derived from the absorption of the aggregate used in the crumb pile, which for granite grit was 0.6% (WA24) for the 2/8 mm fraction and 0.4% (WA24) for the 8/16 mm fraction, while for the basalt grit of the 2/8 mm, it was 1% (WA24) and for the 8/16 mm fraction it was 0.7% (WA24). The diversified surface of the aggregate grains, less developed in the case of basalt aggregate and more irregular in the case of granite aggregate, contributes to less adhesion of the basalt aggregate to the matrix and the appearance of a greater number of microcracks in the contact zone between the aggregate and the cement matrix (Fig. **3**).



a) b)

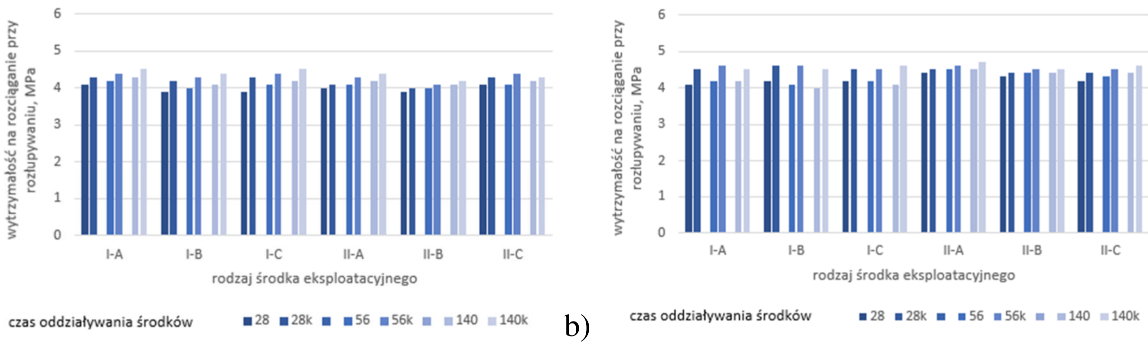
3. Construction of the contact zone between the granite aggregate (a) and the cement matrix in the MG series concrete and between the basalt aggregate (b) and the cement matrix in the MB series concrete.

The influence of operating media on the mechanical parameters of hardened concrete was found. The observed decrease in the average compressive strength of concrete each time, regardless of the type of coarse aggregate, was higher in the case of the first test series (Fig. **4**). A similar phenomenon was observed in the case of splitting tensile strength (Fig. **5**).



a) b)

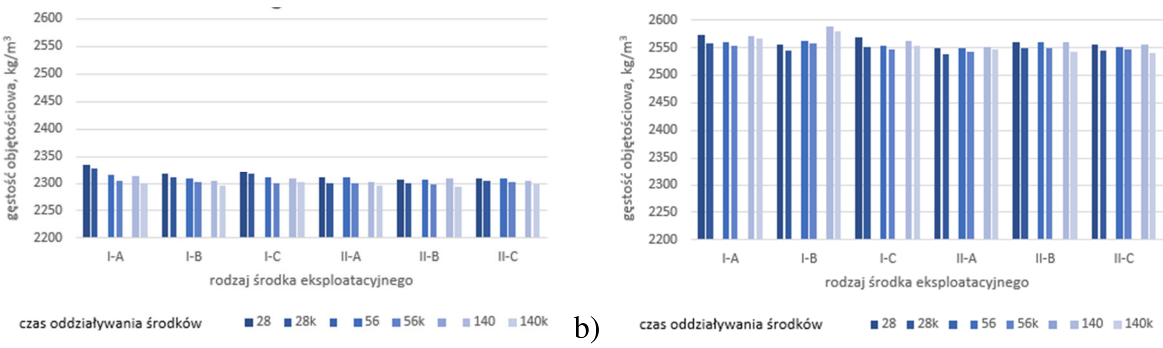
4. Change in the average compressive strength of MG and MB concrete series as a function of operating media exposure time



a) b)

5. Change of average tensile strength during the splitting of MG and MB concrete series as a function of operating media exposure time

As a result of the impact of the operating media, an increase in the bulk density of concrete was observed (Fig. **6**). Operating fluids penetrate the open capillaries of the concrete structure, causing them to be filled, and the extension of the media exposure period additionally contributes to the accumulation of fluids in the pores of the internal structure and the space between the aggregate and the cement matrix. The observed decrease in the bulk density of the control concrete was caused by the conditioning of the concrete in air-dry conditions and the decrease in mass as a result of the loss of unbound structural water.



6. Change in the average bulk density of MG (a) and MB (b) series concretes as a function of operating media exposure time

Summary and Conclusions

The presented results indicate a significant impact of the type of coarse aggregate and operating media on the parameters of hardened concrete. Both the media impact time and the type of operating agents adversely affect concrete, especially in terms of the service life of the pavement. The reduction of mechanical parameters, manifested by a decrease in the value of compressive and tensile strength at splitting and a simultaneous increase in the water absorption of concrete, along with the observed changes in the internal structure of the concrete composite, indicate the possibility of increased propagation of concretes based on basalt aggregate. Regardless of the aggregate used in the crumb heap, a more adverse effect is recorded for the first group of media, i.e. lubricants.

Source materials

[1] Ajagbe W.O., Omokehinde O.S., Alade G.A., Agbede O.A., Effect of crude oil impacted sand on compressive strength of concrete, Construction and Building Materials, No. 26, 9-12, 2012.

[2] Bastian S., Odporność betonu na oleje impregnacyjne, Cement – Wapno - Gips, nr 7-8, 204-211, 1960.

[3] Blankenhorn P. R., Baileys R. T., Gowen D., Kline D. E., Cady P. D., The effects of linseed oil on the compressive strnegth of concreto, Cement and Concrete Research, Vol. 8, nr 4, 513-516, 1978.

[4] Blankenhorn P. R., Barnes D., Gowen D., Kline D. E., Cady P. D., Penetration of concrete with various linseed oil/mineral spirits mixtures, Cement and Concrete Research, Vol. 9, nr 3, 353-364, 1979.

[5] Diab H., Compressive strength performance of low – and high strength concrete soaked in mineral oil, Construction and Building Materials, No. 33, 25-31, 2012.

[6] Duane B. W., The behaviour of airfield rigid pavements under the influence jet fuel, lubricating and hydraulic fluids and cyclic heat loading by F/A-18 APU Exhaust, Civil Engineering, School of Enginering and Information technology, University of New South Wales at the Australian Defense Force Academy, 2016.

[7] Ejeh S.P., Uche O.A.U, Effect of crude oil spill on compressive strength of concrete materials, Journal of Applied Sciences Research, Vol. 5, No. 10, 1756-1761, 2009.

[8] Hironaka M.C., Malvar L.J., Jet Exhaust Damaged Concrete, Concrete International, Vol. 20 No. 10, 32-35, 1998.

[9] Linek M, Żebrowski W., Wolka P.: Zmiana parametrów fizycznych i wytrzymałości na ściskanie betonu lotniskowego pod wpływem hydraulicznego oleju mineralnego, Materiały Budowlane, 11, 2016, DOI: 10.15199/33.2016.11.6229.

[10] Linek M., Nita P., Żebrowski W., Wolka P.: Influence of operating media on the parameters of cement concreto intended for airfield pavements, Journal of KONBiN, 2019, vol. 49, is.4, DOI: 10.2478/jok-2019-0078.

[11] Linek, M.: Beton nawierzchniowy o podwyższonych parametrach fizycznych i mechanicznych na działanie wymuszonych obciążeń temperatury. Kielce, praca doktorska, 2013.

[12] McVay M., Rish J., Sakezless C., Mohsen S., Beatty C., Cements Resistant to Synthetic Oil, Hydraulic Fluid and Elevated Temperature Environments, ACI Materials Journal., Vol. 92, Issue 2, 155-163, 1995.

[13] McVay M.C., Smothson L.D., Manzione Ch., Chemical damage to airfield concrete aprons form heat and oils, ACI Material Journals ,Vol.90, nr 3, 253-258, 1993.

[14] Nita P.: Budowa i utrzymanie nawierzchni lotniskowych, WKŁ, Warszawa, 2008.

[15] NO – 17A – 204:2015 Nawierzchnie lotniskowe. Nawierzchnie z betonu cementowego. Wymagania i metody badań.

[16] PN-EN 206-1 Beton. Wymagania, właściwości, produkcja i zgodność.

[17] Rzepka M., Badania długookresowej odporności korozyjnej stwardniałych zaczynów cementowych stosowanych w wiertnictwie, Nafta-Gaz, nr 7, 451-460, 2017.

[18] Shill S. K., Al.-Deen S., Ashraf M., Concrete durability issues due to temperaturę effects and spillage at military airbase – A comprehensive review, Construction and Building Materials No. 160, 240-251, 2018.

[19] Watson A.J., Oyeka C.C., Oil permeability of hardened cement pastes and concrete, Magazine of Concrete Reasearch, Vol. 33, No.115, 85-95, 1981.

[20] Żebrowski, W. Wpływ mediów wykorzystywanych w eksploatacji statków powietrznych na właściwości stwardniałego betonu nawierzchniowego i jego trwałość, Kielce, praca doktorska, 2019.