Construction and Building Materials 160 (2018) 240–251

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Concrete durability issues due to temperature effects and aviation oil spillage at military airbase – A comprehensive review

Sukanta Kumer Shill [a], Safat Al-Deen [a,*], Mahmud Ashraf [a,b]

[a] School of Engineering and Information Technology, The University of New South Wales, Canberra, Australia
[b] School of Engineering, Deakin University, Waurn Ponds Campus, VIC 3216, Australia

HIGHLIGHTS

- A comprehensive review of the existing literature investigating military airfield durability problem is presented.
- The actual degrading mechanism causing this durability problem is discussed.
- Some recommendations for addressing this problem are also presented.

ARTICLE INFO

Article history:
Received 6 July 2017
Received in revised form 8 November 2017
Accepted 8 November 2017

Keywords:
Airbase concrete pavement
Concrete durability
Jet exhaust
Chemical damage
Thermal degradation

ABSTRACT

Military airbase pavement concrete, especially parking aprons, are regularly exposed to extremely severe circumstances that are not usually experienced by other concrete pavements. Aprons are regularly exposed to hydrocarbons (engine oil, hydraulic fluid, and jet oil), extreme heat shocks, and varied lengths of repetitive cyclic heat loading. As a result, the rapid development of scaling, damage to the pavement in the form of thin flat planar pieces that either flake or peel away from the wearing surface of the concrete pavement, is a regular occurrence on these airbases. This scaling can generate significant amounts of foreign object debris (FOD) in the form of released aggregate and poses a grave threat to the safety of both personnel and assets. Considering this, the paper presents a comprehensive review of the existing literature investigating this serious issue raised by the Australian Air Force. In this review, the real environment and boundary conditions that these airfields are subjected to, which causes rapid scaling, are identified. Furthermore, the actual degrading mechanism including the damaging compounds likely to present in the engine oil, hydraulic fluid and jet oil and their chemical reactions to Portland cement concrete (PCC) are presented. The study also discusses the influence of strength of concrete, moisture content, water-cement ratio (w/c) and the permeability of concrete on the durability of the military airbase concrete. Finally, the authors recommend possible binders, aggregates, and additive materials that could be suitably used in the military airbase concrete to mitigate the addressed issues.

Contents

* Corresponding author.
E-mail address: s.al-deen@unsw.edu.au (S. Al-Deen).

https://doi.org/10.1016/j.conbuildmat.2017.11.025
0950-0618/

1. Introduction

Portland cement concrete (PCC) is a widely used construction material and is widely used in parking aprons and pavements of the military airbase around the world. The military airbase concrete surfaces, especially aprons are regularly exposed to extremely severe circumstances not often experienced by other concrete. In addition to the expected dynamic loads of jet fighters, transport aircraft, and bombers rolling over the surface, these pavements are often exposed to different hydrocarbons (engine oil, hydraulic oil, and jet fuel), extreme heat shocks, and varied lengths of repetitive cyclic heat loading.

Typically, concrete is non-combustible and has good fire-resistance [1]. However, Mcvay et al. [2] reported that the United States Air Force and Navy have been experiencing concrete damages in their airbase due to the effect of high temperature and/or the effect of the chemical attack by jet fuel, hydraulic oil, and lubricants. Moreover, military airbases in Australia have been experiencing concrete scaling damages for over three decades, since F/A-18 jets were purchased and placed into service in 1984 [3]. Usually, such concrete damage takes place in the form of either scaling or peeling off aggregate from the wearing surfaces, which is a regular occurrence on the military airbase concrete. This scaling phenomenon was observed at the parking apron within the first six to eighteen months because of cyclic running and maintenance of aircraft on concrete [2]. Scaling developed progressively at a shallow depth of 6 mm–13 mm beneath the top surface of concrete [2,4]. However, the Department of the Air Force of USA stated in their engineering technical letters that scaling damage occurs on the top 25–50 mm of the pavement [5]. This scaling can generate a significant amount of foreign object debris (FOD) in the form of released aggregate and poses a significant threat to the safety of both aircraft and personnel. FOD of any quantity is not tolerated in the military airbases as a single piece of loose aggregate entering into a jet engine could trigger explosion causing significant damage to loss of assets and personnel [6]. As reported in the airfield pavement maintenance manual (APMM) of the Royal Australian Air Force (RAAF), scaling alone can classify the pavement as failed, and scaling can be a severe hindrance to the safe operation of aircraft [7].

Originally, most of the jet engines require an external starter motor to make the aircraft more self-sustaining. Auxiliary power units (APUs) have subsequently been added to many jet aircraft to make them more self-sufficient. APUs are essentially small jet engines that can be used to start the main engine and provide electrical and hydraulic power prior to starting the main engine start or providing power during an unexpected engine shut down. In most aircraft, the APUs exhaust is directed upwards or parallel to the ground surface. However, in the case of the F/A-18s and the B-1, the APU exhaust is directed downwards. These downward facing APUs exert the exhaust gas on the military airbase concrete at an angle of 45 °C, and measured surface temperature of concrete is approximately 175 °C [8]. Fig. 1 shows an APU at the bottom of an F/A-18, which is clearly visible in the centre of the photo.

Fig. 2 shows a scaling on the surface of a military airbase concrete. In the centre of Fig. 2, an old deep scaling is clearly visible, where aggregates were peeled off from the wearing surface of the concrete. This kind of damage is a source of FOD, and are observed more frequently in the vicinity of the APUs exhaust impinging the concrete. Additionally, a large amount of spilled engine oil, hydraulic fluid, and vented jet fuel from the aircraft are also found regularly in the same region of pavement where APUs exhaust impinges concrete. It is also to be noted that the jets usually park in roughly the same location every time, causing localised damage to some areas of aprons.

Recently, studies on the behaviour of concrete at elevated temperatures is a growing topic, which is quite related in airfields concrete [9–12]. However, military airfields concrete is subjected to more complicated loading scenarios due to the addition of impact

Fig. 1. Underbelly of an F/A-18 with APU featured in the centre of the photo [3].

Fig. 2. Scaling at the top layer of the military airbase concrete.