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Superseding ARP1821

Aircraft Ground Flotation Analysis Methods

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) includes recommended ground flotation analysis methods for both paved and unpaved airfields.

1.1 Purpose:

The purpose of this document is to identify the recommended aircraft ground flotation analysis methods that should be used for aircraft landing gear design.

2. REFERENCES:

1. AIR1780, Aircraft Flotation Analysis
2. Computer Program for Concrete Airport Pavement Design, Program PDILB, by Robert G. Packard, Portland Cement Association, 1968
3. ICAO, Aerodrome Design Manual-Part 3-Pavements-First Edition, 1977:
 - a. Load Classification Number Method (LCN), Section 1.3, Method (LCN), Section 1.3, Method C)
 - b. The Load Classification Group (LCG) Method of Classifying Aerodromes and Aircraft (LCN/LCG), Section 3.3. (U.K. Practice)
4. Procedures for Development of CBR Design Curves, by A. Taboza Pereira, Instruction Report S-77-1, U.S. Army Engineer Waterways Experiment Station, June 1977
5. Recommended Standard Data Format of Transport Airplane Characteristics, National Aerospace Standards, NAS 3601, Aerospace Industries Association of America, June 1968
6. Airport Pavement Design and Evaluation, AC 150/5320-6C, Federal Aviation Administration, December 1978

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2. (Continued):

7. Airport Pavement Design for the Boeing 777 Airplane, AC 150/5320-16, Federal Aviation Administration, October 1995
8. ICAO, Aerodrome Design Manual-Part 3-Pavements-Second Edition-1983:
Procedure for Pavements Meant for Heavy Aircraft (ACN-PCN Method) Section 1.1
9. Aircraft Ground Flotation Analysis Procedures-Paved Airfields, by Dale E. Creech and Donald H. Gray, ASD TR-7043, Aeronautical Systems Division, USAFSC, January 1971 (AD 720273)
10. Evaluation of Aircraft Landing Gear Ground Flotation Characteristics for Operation from Unsurfaced Fields, by Donald H. Gray and Donald E. Williams, ASD TR-68-34, Aeronautical Systems Division, USAFSC, September 1968 (AD 843585)
11. Planning and Design of Roads, Airfields, and Heliports in the Theater of Operations, FM 5-430/AFJMAN 32-8013 Vol. 2, Department of the Army and the Air Force, September 1994
12. Paving, and Surfacing Operations, TM 5-337, Department of the Army, February 1966
13. Design of Aggregate Surfaced Roads and Airfields, TM 5-822-12, Department of the Army, September 1990
14. Rigid Pavement Design for Airfields, MIL-HDBK-1021/4, Department of the Navy, April 1987
15. Flexible Pavement Design for Airfields, DM-21.3/TM 5-825-2/AFM 88-6, Chap. 2 (Tri-Service) - Department of the Army, Navy, and Air Force, August 1978

3. AIRCRAFT GROUND FLOTATION:

Aircraft ground flotation refers to the ability of an aircraft to operate on existing airfield pavements and is a process of trade-offs between demands for aircraft landing gears with acceptable ground loading pressure and the desirability for light landing gear weight for efficient flight and mission characteristics. The flotation analysis process can relate to the setting of landing gear characteristics for contemplated new aircraft designs, or it can relate to limitations of gross weight and tire pressure for existing aircraft mission capability to a particular landing site.

4. RECOMMENDED ANALYSIS METHODS:

Flotation requirements involve a combination of gross weight, the distribution of that weight (number of tires) to the supporting pavement, the spacing of tires to limit overlap of load-distribution effects within the supporting pavement or unpaved ground, and the intensity of surface tire loading as represented by the average tire contact pressure (tire load/tire contact area).

Results obtained from flotation analyses can vary significantly by the type of analytical method used for design of pavements and unpaved operating areas. There is a direct but variable relationship between the character of pavement subgrade and structure, and the air vehicle wheel spacing and to a lesser degree (reduced) tire pressure in avoiding overlap of load distribution effects within the supporting pavement or unpaved ground. In the past, the diversity of pavement design and evaluation methods applied to flotation analyses has led to confusion. More recently, however, a developing consensus has led to the overall summary of recommended methods presented in Table 1.

It is important to realize that results of flotation analyses of low-strength subgrades requiring thick structures for support of loads can be quite different from otherwise identical analyses of good-strength subgrades requiring only relatively thin structures for load support. Thus, the manner in which a particular pavement design method evaluates subgrade strength and relates it to load support or flotation will substantially influence quantitative results for a particular aircraft type or contemplated aircraft landing gear designs for a particular landing surface.

Where flotation analysis consists of direct comparisons between aircraft types or between alternative landing gear designs for a new aircraft, the analysis method used has much less significance. In this case a ratio of quantified flotation is involved, and any valid analysis method selected will tend to provide a similar ratio even where direct quantities differ between methods.

4.1 Paved Airfields:

On rigid pavements, flotation analyses for commercial and civil aircraft should be made using the Portland Cement Association (PCA) method, using the PDILB computer program. The Load Classification Number (LCN) and the Load Classification Number/Load Classification Group (LCN/LCG) methods are also used in some instances.

FAA Advisory Circulars AC150/5320-6D and AC150/5320-16 and the ACN/PCN methods are also acceptable for flotation analysis. The Port Authority of New York and New Jersey has their own pavement design method. For military aircraft, flotation on rigid pavement is analyzed per ASD-TR-70-43 for USAF and U.S. Army, and per MIL-HDBK-1021/4 for the U.S. Navy. A precaution regarding rigid pavement assessments concerns the common use of both "center load" and "edge load" methods for design and evaluation. For comparative ground flotation determinations either method should provide useful results, but comparisons where the different methods have been used will not be correct.

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TABLE 1 - Recommended Flotation Procedures

Usage	Service	Runway Type	Method/Reporting	Remarks
Commercial and Civil		Rigid	PCA LCN LCN/LCG	Analyze per NAS 3601 using PDILB and Instruction Report S-77-1. LCN temporarily remains in 3601.
		Flexible	S-77-1 LCN LCN/LCG	
		Rigid and Flexible	AC150/5320-6D ACN/PCN AC150/5320-16	FAA advisory circular. Official applicability by ICAO Nov. 1 1981.
		Other	PANYNJ	Applies to airports under the jurisdiction of the Port of New York and New Jersey Authority.
Military	USAF and Army	Rigid and Flexible	ASD-TR-70-43 LCN/LCG ACN/PCN	The military now reports pavement bearing strength in terms of ACN/PCN.
		Unpaved	ASD-TR-68-34	Does not address aggregate surfaced airfields.
		Matted and Membrane	Fm 5-430 TM 5-337 MP S-73-27	FM 5-430/AFJPAM 32-8013, Vol. 2 replaces TM 5-330/AFM 86-3 MP S-73-27 presents mat design criteria.
	Navy	Rigid	MIL-HDBK 1021/4	Handbook is being revised and will become DM 21.10.
		Flexible	DM 21.3	DM 21.3 is being incorporated into DM 21.10.
	Defense Mapping Agency	Rigid, Flexible, Unpaved	LCN/LCG ACN/PCN	Including ACN/PCN if data is available.

4.1 (Continued):

On flexible pavement, flotation analyses for commercial and civil aircraft should be made in accordance with U.S. Army Engineer Waterways Experiment Station Instruction Report S-77-1. The USAF and U.S. Army flexible pavement methods contained in ASD-TR-70-43 can continue to be used. The U.S. Navy and updated Air Force and Army methods are in the Tri-Service, "Flexible Pavement Design for Airfields," manual DM-21.3 (also TM 5-825-2 and AFM 88-6, Chap. 2). The ACN/PCN method may also be used for analysis.

The Defense Mapping Agency Aerospace Center (DMAAC) continues to utilize LCN/LCG, and additionally reports ACN/PCN data where available.

4.2 Unpaved Airfields:

The recommended methods for aircraft flotation analyses on unpaved airfields are described in the following paragraphs.